EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH-RISE BUILDING USING REINFORCED CONCRETE AT SEMERA

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DECLARATION

I hereby declare that this thesis entitled with **"Effect of Concrete Grade Enhancer Admixture on Structural Design of High-Rise Building using Reinforced Concrete at Semera"** was composed by myself, with the guidance of my advisor, that the work contained herein is my own, and that this work has not been submitted, in whole or in part, for any other degree or processional qualification.

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CERTIFICATE

This is to certify that the thesis prepared by **Mr. Yohannes Sefiw Andarge** entitled with **"Effect of Concrete Grade Enhancer Admixture on Structural Design of High-Rise Building using Reinforced Concrete at Semera"** and submitted with in partial fulfillment of the requirements for the Degree of Master of Science complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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DEDICATION

This work is dedicated to you, the reader; I greatly appreciate your interest and motive towards for understanding the effect of concrete grade enhancer admixture on structural design of high rise buildings and contributing your effort in aware of Consulting Companies, Contractors, Engineers, Investors and others to use MegaFlow SP1, High Range Water Reducing Superplasticiser or equivalent concrete grade enhancer admixture and initiate Material Engineers for creation of concrete grade enhancer admixture using locally available materials, so that better concrete performance and lesser structural design cost are produced and implemented in the country.

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ABSTRACT

The thesis deals about the effect of concrete grade enhancer admixture on structural design of high-rise building using reinforced concrete at Semera, Ethiopia. Semera is a highly seismic area with a few apartment blocks, residence, hotels, administrative buildings, stadium and Airport. The research aims to investigate the effect of this admixture in related to structural design cost, concrete performance and other structural design related parameters using laboratory tests and sample structural designs.

The laboratory test is done using 32 cubic and 32 prism specimens for compressive and flexural strength tests to determine concrete performance in related concrete workability, ductility, compressive and flexural strength. Among the total 64 concrete samples half of them is prepared using concrete grade enhancer admixture called “MegaFlow SP1, High Range Water Reducing Superplasticiser”. The average value of slump height, compressive and flexural strength of the selected trial mix is 3.76 Cm, 33.35 Mpa and 4.954 Mpa for C-25 concrete (concrete without admixture) and 5.22 Cm, 44.84 Mpa and 7.047 Mpa for C-40 concrete (concrete with admixture) respectively. Moreover, C-40 concrete is more ductile than C-25. The amount of admixture added on mixing proportion of C-25 concrete to get C-40 concrete is 2% by weigh of cement or 1 kg for one bag of cement with water cement ratio of 0.3. Accordingly, the mix ratio for C-40 concrete is 1:1:2:3 by volume with a box size of 50x40x18cm.

Sample structural design is done for G+2, G+7 & G+12 multipurpose buildings with typical floor plan placed on 957m^2 at Semera using C-25 and C-40 concrete types. The structural design cost using C-40 concrete is reduced by 7.74%, 12.79% and 22.03% for G+2, G+7 & G+12 buildings respectively in compare with C-25 concrete. However, even if the total cost of structural design is reduced, the usage of admixture for slab and staircase is not significant reduced structural design cost. Due to usage of admixture, the floor area which will be occupied by columns is reduced by 23.61% (2m^2), 17.84% (2.59m^2) and 12.45% (2.39 m^2) for G+2, G+7 and G+12 buildings respectively. Furthermore, the floor clear height also increased by 1.79% (5cm), 1.82% (5cm) and 3.70% (10cm) for G+2, G+7 and G+12 buildings respectively due to reduction of beam depth. The percentage of cement saved due to usage of admixture in place of cement is 32.08 % or 170 kg with 44.01 % or 2992.71 birr cost reduction for 1m^3 concrete work.

Considering the facts, it is highly recommended to use a concrete mix with concrete grade enhancer admixture for structural design of buildings and other reinforced concrete structures.

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LIST OF ABBREVIATIONS

C-5	A concrete with 5mpa cubic compressive strength
M10	A concrete with 10mpa cubic compressive strength
M15	A concrete with 15mpa cubic compressive strength
M20	A concrete with 20mpa cubic compressive strength
M25	A concrete with 25mpa cubic compressive strength
M30	A concrete with 30mpa cubic compressive strength
M40	A concrete with 40mpa cubic compressive strength
G+2	Ground plus two floor building
G+7	Ground plus seven floor building
G+12	Ground plus twelve floor building
C-15	A concrete with 15mpa cubic compressive strength
C-25	A concrete with 25mpa cubic compressive strength
C-40	A concrete with 40mpa compressive strength
C-105	A concrete with 105mpa cubic compressive strength
S-240	A steel with 240mpa yield strength
S-275	A steel with 275mpa yield strength
S-300	A steel with 300mpa yield strength
S-400	A steel with 400mpa yield strength
S-600	A steel with 600mpa yield strength
PLC	Private Limited Company
ES EN	Ethiopian Standard based on Europe Norm
GFS	Panel name for ground floor slab
FS	Panel name for floor slab
RS	Panel name for roof slab
EBCS	Ethiopian Building Code of standard
SP	Superplasticiser
UTM	Universal Testing Machine
No	Number
ACI	America Concrete Institute
i.e	This means
VFR	Variable functional room
SDL	Supper dead load
DL	Dead load
LL	live load
HCB	Hollow block concrete

LIST OF SYMBOLS

L	Length
T	Thickness
γ_c	Partial factor of safety for concrete
γ_s	Partial factor of safety for steel
f_{cd}	Design compressive strength of concrete
f_{yd}	Design tensile strength of steel
f_{yk}	Characteristic tensile strength of steel
$f_{ck, cube}$	Characteristic cubic compressive strength of
f_{ctd}	Design tensile strength of concrete
q_b	Basic Velocity pressure
V_b	Basic Velocity
$V_{b,o}$	Fundamental basic wind velocity
C_{dir}	Directional factor
C_{season}	Season factor
ρ	Air density
H	Height of the building
T_1	Fundamental period of vibration
C_t	Factor for type of structure frame
A_{ref}	Reference area
C_sC_d	Structural factor
F_{net}	Net wind force
$S_d(T)$	Design spectrum at period T
B	The lower bound factor for the horizontal design
S	The soil factor
γ_I	Importance factor
g	acceleration of gravity
G_k	Dead load
φ	Load type coefficient
W	Weight of combined actions
γ	Unit weight of material
V_{Rd}	Diagonal compression resistance
V_s	Net shear
b_w	Width
V_c	Concrete shear resistance
M_{sd}	Design moment
Z_e	Reference height
B	Cross wind width
H	Height
$C_{e(}Z)$	Exposure coefficient
Z	Elevation
q_p	Characteristic peak velocity pressure
C_{pe}	External pressure coefficient
A	Area
e	Exposer width
d	Wind parallel width
C_{pi}	Internal Wind pressure coefficient
μ	Opening ratio
W_e	External wind pressure
W_i	Internal wind Pressure
W_{net}	Net Wind Pressure
W_i^-	Negative internal wind Pressure
W_i^+	Positive internal wind Pressure
C_{pi}^-	Negative internal wind pressure
C_{pi}^+	Positive internal wind pressure
$F_{w,e}$	External wind force
$F_{w,i}$	Internal wind force
a_g	Design ground acceleration
q	The behaviour factor
η	The damping correction factor
ξ	the viscous damping ratio of the
α_0	The bed rock acceleration ratio
Q_k	Live load
H	Height of the building
q_k	Area live load
V_{sd}	Design shear
M_{xfadj}	Adjusted field moment in Y
M_{yfadj}	Adjusted field moment in Y
d	Effective depth
H	Height
D	Total Depth

Φ_m – Main reinforcement diameter
Φs Stirrup diameter
α_{xs} Support moment coefficient in X
α_{xf} Field moment coefficient in X
α_{ys} Support moment coefficients in Y
α_{yf} Field moment coefficients in Y
t_s Thickness of slab
t_w Thickness of wall
t_p Thickness of plastering
t_{ff} Thickness of floor finish
M_{xs} Support moments in the X
M_{xf} Field moments in the X direction
ΔM_{xs} Support moment change in X
M_{ys} Support moment change in Y
Mxs_{adj} Adjusted support moment in X
Mys_{adj} Adjusted support moment in Y
α_i Moment coefficient
M_i Slab moment
L_x Shorter span length for slab
L_y Longer span length for slab
L_e Longer span length for beam
W_p Weight of plaster
W_{cs} Weight of cement screed
W_{ff} Weight of floor finish
W_{pw} Weight of partition wall
W_L Wind load
V_{Rd2} Wide beam shear resistance
V_{d1} Net developed punching shear
V_{Rd1} Punching resistance
V_1 Developed punching shear
V_{d1} Developed wide beam shear
σ_{ult} Ultimate soil bearing capacity
σ_{all} Allowable soil bearing capacity
σ_{max} Maximum contact pressure
σ_{min} Minimum contact pressure
L_e Effective length
Y_m Center of mass in Y

P_d Design Load
ρ_{min} minimum steel ratio
As_{min} Minimum required area of steel
I Importance factor
S Site Coefficient for soil
T_1 Fundamental period of vibration
γ Behavior factor
F_b Base shear
As_s Secondary reinforcement area
P Concentrated load
M_{ys} Support moments in the Y
M_{yf} Field moments in the Y direction
As Reinforcement area
g_d Area dead load
q_g Area live load
W Weight
d_s Stirrup diameter
ρ_{bal} Balanced steel ratio
a_s Area bar
d_m Main bar diameter
M Moment capacity
ε_{yd} Steel strain
ε_{cu} Maximum concrete strain
S Spacing
S_{cal} Calculated spacing
S_{prv} Provided spacing
S_{max} Maximum spacing
K Stiffness
ρ_{cal} Calculated steel ratio
As_{prv} Provided reinforcement area
I Second moment of inertia
H Horizontal reaction at the bottom
Ϭ Displacement at the top of the story
M_c^{max} Maximum Cantilever moment
$N_{u,Rd}$ Buckling resistance
A_{S2} Reinforcement area for top
A_{S1} Reinforcement area bottom

X_m	Center of mass in X
λ_{cal}	Calculated slenderness ratio
e_e	Primary eccentricity
e_a	Additional eccentricity
N	Vertical reaction at the bottom of
e_{tot}	Total eccentricity
e_2	Secondary eccentricity
T_B	The lower limit of the period of the constant spectral
T_C	The upper limit of the period of the constant spectral
T_D	The value defining the beginning of the constant
ψ_{Ei}	The combination coefficient for variable action in the building
X_m	Center of the building at each floor in X direction
Y_m	Center of the building at each floor in Y direction
X_i	Center of the corresponding mass in X direction
Y_i	Center of the corresponding mass in Y direction
ψ_{2i}	The combination coefficients for the quasi-permanent value of variable action q_i
f_t	Target strength for concrete

1. INTRODUCTION

1.1 BACKGROUND AND JUSTIFICATION

Now a day there are different types of admixtures such as Set-Retarding, Air-Entrainment, Water-Reducing, Accelerating, Shrinkage Reducing, Super plasticizers, Corrosion-Inhibiting and the like that are added to a concrete mix for various purpose. Among various types of admixtures, this research uses super plasticizer admixture to produce high-strength concrete at water cement ratios ranging from 0.3 to 0.4 with a high slump in the range of seven to nine inches. Such type of admixtures are highly used in the construction industry to get high-strength concrete. In the history of admixture Japanese's get more than 100mpa concrete using concrete compressive strength increaser admixture. The American Concrete Institute also got 250mpa compressive strength concrete with 25mpa tensile strength using steel chips in the concrete mix with super plasticizer admixtures. However, the usage of such types of admixture in our country, Ethiopian is not popular except a little trend in usage of admixtures like accelerating admixtures.

Usage of such types of super plasticizer admixture or structural design using C-40 (Concrete with concrete grade enhancer admixture) in our country gives various advantages such as it helps to get high grade concrete with less concrete works cost in compere with high concrete grade with increasing cement amount, it make the construction management easy to get high grade concrete, it saves cement, it increase concrete performance in related to concrete workability, ductility and strength, it reduces floor area which will be occupied by columns, it increases floor clear height, it reduce the magnitude of earthquake load by reducing total weight of structures and it has less structural design cost. Moreover, the concrete grade enhancer admixture helps to make the concrete mix to get its strength earlier and this shorten construction period.

Considering such advantage of using concrete grade enhancer admixture in our country, the research aims to investigates the general effect of concrete grade enhancer admixture on structural design of high-rise building using super plasticizer admixtures called “MegaFlow SP1, High Range Water Reducing Superplasticiser” at Semera, Ethiopia.

Structural design is the methodological investigation of the stability, strength and rigidity of structures. The basic objective in structural analysis and design is to produce a structure capable of resisting all applied loads without failure during its intended life; here in order to investigate the effect of concrete grade enhancer admixture on structural design of high rise building accurately, the design should be strong, serviceable and economical. Structural design may done for Buildings (Residential, Institutional, Commercial, and Industrial), Bridges **(**Arch, Cantilever, Cable, and Suspension), and Water structures **(**Dam, Conveyance structure, and Head work structure). Generally structural design may be done for Reinforced concrete, Steel, Timber and Stone/Masonry; among these the research investigates the effect of concrete grade enhancer admixture on structural design of high-rise building with reinforced concrete using typical architectural plan of G+2, G+7 and G+12 multipurpose buildings.

Semera, which is the capital city of Afar regional state, is found in one of the lowland regions of Ethiopia with an altitude of 422 meters above sea level at a distance of 620 kilo meters from Addis Ababa with geographical location of $11^{o}47'32''$N, $41^{o}0'31''$E. It is characterized as the cradle of human origin through the discovery of LUCY, SELAM, ARDI and a lot more ancient human remains with moving volcano called "ERTALE". Because of such highly tourist destination area, a lot of tourists travel to the capital city, Semera. But there is no as such highly attractive modern high-rise building in the city which gives quality service for those tourists. It has only a few apartment blocks, public and administrative buildings, pension houses, hotels and traditional residence with stadium and airport passenger terminal building under construction. For this matter modern and attractive high-rise building should be constructed to increase political, social and economic value of the city. But despite of this matter, there is a problem related to high effect of lateral loads. The construction of such high-rise building using steel structure will be highly affected by wind. Whereas when the building planned to construct using C-25 concrete, it needs higher cross sectional dimension of structural elements; and this increase effect of earth quake. On such instant the high-rise building should be designed within moderate weight to reduce the effect of earthquake to have economical structural design. Following that, the research done by introducing concrete grade enhancer admixture to increase concrete compressive strength to reduce cross sectional dimension of structural elements to reduce structural design cost.

The research includes determining the amount of admixture to be added to get C-40 concrete using the same mixing proportion of cement, sand and aggregate used for C-25 concrete through mix design test. Then structural design of the building using both C-25 and C-40 concrete is done with their cost comparison analysis. Moreover, the research also investigates the effect of this admixture on performance of the concrete using cubic compressive and one point flexural strength tests.

1.2 OBJECTIVE

1.2.1 GENERAL OBJECTIVE

The primary and foremost objective of the research is to investigate the effect of concrete grade enhancer admixture on structural design of high-rise building using reinforced concrete structure at Semera in related to structural design cost, concrete performance and other parameters.

1.2.2 SPECIFIC OBJECTIVE

Specifically the research has the following objectives;

1. To design safe, serviceable and economical structural design for high-rise building using C-25 concrete (concrete without concrete grade enhancer admixture) and C-40 concrete (concrete with concrete grade enhancer admixture) to determine the effect of concrete grade enhancer admixture on structural design cost;
2. To determine the amount of admixture to be added on the concrete mix to get 40mpa compressive strength from mixing proportions cement, sand aggregate of C-25 concrete;
3. To determine the effect of concrete grade enhancer admixture on performance of concrete in related to concrete workability, ductility and compressive strength;
4. To determine the effect of concrete grade enhancer admixture related on building height;
5. To determine the percentage of cement saved due to the usage of concrete grade enhancer admixture in place of cement;
6. To determine the percentage of area reduction which will be occupied by columns and;
7. To determine the percentage of increasing floor clear height due to reduction of beam depth;

1.3 SIGNIFICANCE OF THE RESEARCH

Generally the main importance of the research is to investigate the effect of concrete grade enhancer admixture on structural design of high rise building using reinforced concrete in related to structural design cost, concrete performance and other parameters.

Specifically, the research gives the following major benefits;

1. Enables to know which concrete grade has less structural design cost and better concrete performance;
2. Enables to know the effect of concrete grade enhancer admixture on structural design cost in related to height of the building;

3. Determines the percentage of cement saved due to using concrete enhancer admixture in place of cement;
4. Determines increasing floor area and clear height percentage due to reduced cross sectional dimension of structural elements due to the presence of concrete grade enhancer admixture ;
5. Create adaptation of using concrete grade enhancer admixture as the fifth ingredient of concrete mix and the concrete mixing proportion changes like 1:1:2:3; which is 1 for one bag of cement, 1 for 1 kg of concrete grade enhancer admixture, 2 for two box of sand and 3 for three box of aggregate with 15 liter of water for C-40 concrete;
6. Create adaptation C-40 concrete instead of C-25 by adding 7.2 liters of concrete grade enhancer admixture from C-25 concrete mix proportion of cement, sand and aggregate;
7. Initiation of Material Engineers for creation of concrete grade enhancer admixture using locally available materials;
8. Initiation of Investors for creation of companies that manufactured and supply concrete grade enhancer admixture using locally available materials;

2. LITERATURE REVIEW

A lot of researches haven been made on the effect of adhesives on the performance of concrete such as Akindahunsi and Uzoegbo, June 2, 2015, “Strength and Durability Properties of Concrete with Starch Admixture”; Seyd Ali Rizwa, 2006 “Master’s Thesis in structural Engineering on High-Performance mortar and concrete using secondary row materials”; Annaamalai, 2015, “Effect of Partial Replacement of Cement with Neem Gum on the Strength Characteristics of High Performance Concrete”; Kamal Henri Khayat, 1995 “ Effect of Antiwashout Admixture on Fresh Concrete Properties”; Venu Malagavell, 2015 “Strength and Workability Characteristics of Concrete by using Different super plasticizers” and the like.

2.1 SAMPLE LITERATURE REVIEW SUMMARY

The title of the research is *“*effect of partial replacement of cement with Neem Gum on the strength characteristics of high performance concrete” and it was published on International Journal of ChemTech Research by Annaamalai in the year 2015.

In this journal Neem Gum, which is extracted from Azadirachta indica trees and crushed in to powder form, is used in concrete mixes as partial replacement of cement to increase compressive strength of concrete with better workability. This tree also used for treatment of urinary disorders, antiseptics, antimicrobials, diarrhea, fever and bronchitis skin diseases. Studies were done on local adhesive by earlier researchers such as Ashraf Mahmoud Saleh and Osman User Dabluk before M.G.L.Annaamalai to get high compressive strength of concrete with good workability.

The research was done using a concrete mix of 0.1, 0.2, 0.4, 0.6, 0.8, 1, 1.2 and 1.5 percent of Neem Gum by weight of ordinary portland cement and laboratory experiment results were analyzed to investigate the effect of this adhesive on workability of fresh concrete and compressive, tensile, flexural strength of harden concrete.

The experiment was done using of 10 and 20 mm coarse aggregate with a ratio of 1:1.78 and a fine aggregate of land quarried sand passing through 4.57mm ASTM sieve with fineness modulus of 2.5. All the concrete ingredients were mixed using tap water with water-cement ratio of 0.45 at constant workability of 30-60 mm slump height. The concrete mixing proportions was 230 liter/m^3 of water, 511 kg/m^3 of cement, 623 kg/m^3 of fine aggregate and 1016 kg/m^3 of course aggregate with a total density of 2380kg/m^3 fresh concrete.

The concrete specimens were prepared using cubes of size 150x150x150 mm for compressive strength tests, cylinders of size 100x300 mm for splitting tensile strength test and prisms of 10x100x500 mm for flexural strength test. The casted sample concrete specimens were remolded after 24 hours of casting and cured for 28 days. Then compressive strength test for cube concrete samples were conducted at the age of 7, 14 and 28 days. After compressive strength test was conducted, the crushing strength of concrete with 0.1% Neem Gum was 40.23 mpa, 46.48mpa and 52.6 mpa for 7, 14, and 28 days concrete age respectively. And the crushing strength of concrete with 1.2% Neem Gum was 62.74 mpa, 68.51 mpa and 72.84 mpa for 7, 14, and 28 day's concrete age respectively. Whereas the crushing strength of concrete with 1.5% Neem Gum was 58.77 mpa, 64.89 mpa and 70.43 mpa for 7, 14, and 28 days concrete age respectively.

This shows adding Neem Gum to concrete mix significantly increase compressive strength of concrete with achieved consistency and the optimum content of Neem Gum was determined by testing various concrete samples with different Neem Gum content from 0.1% to1.5%. The maximum compressive strength was found at 1.2% Neem Gum content and the strength suddenly fails at 1.5% Neem Gum content.

Therefore the researcher Annaamalai verified the effect Neem Gum on the strength characteristics of high performance concrete and determined the optimum content of adhesive to obtain maximum compressive strength.

This research is done based on earlier researcher's methods such as conducting compressive strength test to determine the amount of concrete grade enhancer admixture added on concrete mix and the effect of this adhesive on structural design of high-rise building related to structural design cost, ductility and other parameters is investigated.

3. METHODOLOGY

3.1 RESEARCH DESCRIPTION

The research is on the effect concrete grade enhancer admixture on structural design of high-rise building using reinforced concrete at Semera city. It assesses the effect of this admixture on structural design of high-rise buildings by adding a certain amount concrete grade enhancer admixture on mixing proportions of C-25 concrete. The admixture used for research is MegaFlow SP1, High Range Water Reducing Superplasticiser using G+12 multipurpose building with additional G+2 & G+7 buildings for comparison purpose in order to know the effect of concrete grade enhancer admixture related to height of the buildings. Then after, the research investigates the cost and performance comparison of structural design using a concrete type of C-40 by adding concrete enhancer admixture with C-25 concrete type.

Moreover, the research also addressed the effect of concrete grade enhancer admixture on concrete performance and other structural design related parameters.

3.2 RESEARCH METHOD

The research method follows the following steps;

- **Step 1:** Assessment of material and equipment Availability
- **Step1.1:** Check availability of material
- **Step1.2:** Check availability of equipment
- **Step 2:** Literature review
- **Step 3:** Conducting laboratory testes
- **Step 3.1:** Conducting slump tests
- **Step 3.2:** Conducting cubic compressive strength tests
- **Step 3.3** Conducting one point flexural strength test
- **Step 4:** Preparation of typical architectural plan
- **Step 5:** Sample structural design
- **Step 6:** Statistical Interpretation of design and test results
- **Step 7:** Set Research Conclusion and Recommendation

3.2.1 ASSESSMENT OF MATERIAL AND EQUIPMENT AVAILABILITY

3.2.1.1 ASSESSMENT OF MATERIAL AVAILABILITY

The materials used for research are cement, sand, aggregate, concrete grade enhancer admixture with and tap water. All materials except concrete admixture are locally produced and widely available. The admixture is imported from other countries like United Arab Emirates. There are a lot of companies that supply concrete grade enhancer admixture in Addis Ababa; for example AB-HAM Enterprise PLC supplies Mapefluid N140, Water reducer super plasticizer admixture.

All materials used for increasing concrete grade are widely available on the market and there is no any problem related lack of admixture. There are also other companies such as KANMAX Engineering and Trading PLC, SETS Waterproofing General Trading PLC, TDS PLC, SIKA Abyssinia Chemicals Manufacturing PLC, LICON Manufacturing PLC that supplies concrete grade enhancer admixtures.

3.2.1.2 ASSESSMENT OF EQUIPMENT AVAILABILITY

The equipment’s used for research are testing machine for conducting concrete compressive strength, workability and one point flexural test. For conducting such type of tests, equipment’s like compression testing machine, universal testing machine, drum mixer, cubic concrete mold, rectangular prism mold, slum pan and hand tools are required. And all testing equipment’s are available at Addis Ababa Science and Technology University Structural Engineering Laboratory.

3.2.2 LABORATORY TEST

Laboratory tests are required to determine the amount of concrete grade enhancer admixture added to concrete mix using compressive strength test and its effect on ductility of concrete using one point flexural strength test with controlled workability.

3.2.2.1 CUBIC COMPRESSIVE STRENGTH TEST

The compressive strength test is conducted using 15x15x15 cm cubic mold for concrete mixed design. Mix design is done for two type of concrete grades; the first one is for 25mpa compressive strength concrete with 1:2:3 mixing proportions of cement, sand and aggregate by volume without admixture and the second one is for 40mpa compressive strength concrete with 1:2:3 mixing proportions of cement, sand and aggregate by volume with admixture. The size of batching box is 40x50x18 cm or any size combination of the same volume as 0.035 m^3. The concrete workability of both mixes is controlled within acceptable range using slump test and the amount of admixture added to get C-40 concrete is determine by trial of test. The trial amount of added admixture to concrete mix is take from practical and research experience of other works and verified using mix design test.

The number of sample cubic specimens is 16 for C-25 and 16 for C-40 concrete types. Among the 16 cubic samples of concrete, 8 of them are tested at the age of 7 days and the reimaging 8 at the age of 28 days after casting for both type concretes.

3.2.2.2 ONE POINT FLEXURAL TEST

One point flexural strength test is conducted to determine the effect of concrete enhancer admixture on ductility of concrete in related to flexural strength of a concrete members. This test is conducted in parallel with the mix design test using different trial mixes from practical experiences. Once the concrete mix for both C-25 and C-40 concrete is using selected cement, sand and aggregate for tests, sample prism specimens of 10x10x50 cm, 15x15x60 cm and 15x15x75 cm sizes are prepared to conduct flexural strength tests for C-25 and C-40 concretes.

The number of sample prism specimens is 16 for C-25 and 16 for C-40 concrete types. Among the 16 prism samples of concrete, 8 of them are tested at the age of 7 days, and the reimaging 8 at the age of 28 days after casting for both type concretes.

Refer Appendix A for detail explanation of methods and procedures to conduct laboratory tests.

Table 3.1 Laboratory testes

Type of test	**Compressive Strength Test**				**One point Flexural strength test**			
Concrete Grade	**C-25**		**C-40**		**C-25**		**C-40**	
Admixture	Not used		Used		Not used		Used	
Specimen Size	15x15x15 cm		15x15x15 cm		10x10x50 cm		10x10x50 cm	
No of Specimens	16		16		16		16	
Testing time (day)	7	28	7	28	7	28	7	28
No of testing sample	8	8	8	8	8	8	8	8

3.2.3 PREPARATION OF TYPICAL ARCHITECTURAL FLOOR PLAN

A typical architectural is prepared as clearly shown on appendix B for G+2, G+7 & G+12 multipurpose buildings approximately on 1000 square meter area. The plan is the same thought the floors; just it is for the purpose of structural design, in order to investigate the effect of concrete grade enhancer admixture on structural design. The only difference between the architectural designs of each building is the number of floors they have with the same height of 3.20m; since the need of adding G+2 and G+7 buildings is to know the effect of the admixture related to height of the building.

3.2.4 SAMPLE STRUCTURAL DESIGN

Sample structural design is done after a full scale 3D modeling and analysis of the buildings. Structural modeling, load simulations and analysis is done using structural analysis and design software called "ETABSv2013". Following that, sample structural design is done for foundations, columns, beams, slabs and staircases by taking analysis result from 3D structural modeling using both C-25 and C-40 concretes for G+2, G+7 & G+12 buildings.

Refer Appendix C for detail calculation and explanation of sample structural designs.

Table 3.2 Sample structural design

Structural element	**Foundation**		**Column**		**Beam**		**Slab**		**Staircase**	
Type of building	G+2, 7 & 12		G+2, 7 & 12		G+2, 7 & 12		G+2, 7 & 12		G+2, 7 & 12	
Concrete grade	C-25	C-40	C-25	C-40	C-25	C-40	C-25	C-40	C-25	C-40
No Sample Element	3	3	9	9	12	12	1	1	1	1

3.2.5 STATISTICAL INTERPRETATION OF DESIGN AND TEST RESULT

Interpretation of the design and test results is done to know the effect of concrete grade enhancer admixture on structural design of high-rise building in related to the overall structural design cost, performance of concrete and other parameters.

Generally statistical interpretation is made on the following points based laboratory test and sample structural design results.

- Structural design cost comparison of a buildings designed using C-25 and C-40 concrete grades to determine the effect adding concrete grade enhancer admixture on concrete mix;
- Comparison of concrete performance for C-25 and C-40 concrete grades in related concrete strength and workability;
- Comparison of stress-strain curve for C-25 and C-40 concrete grades to see the effect of concrete grade enhancer admixture on concrete ductility;
- Determination cement saved percentage due to using concrete grade enhancer admixture in place of cement;
- Determination of floor area and clear height increasing percentage due to reduced cross sectional dimension of structural elements;

Table 3.3 Research Method

Research Activities	Method used	Remark
1. Concrete performance	Laboratory tests	Using slump, compressive & flexural tests
2. Architectural design	AutoCAD	Using appropriate scale
3. Structural analysis	ETABS	Using limit sate design based on ES EN: 2015
4. Different calculations	Microsoft Excel	Using appropriate formulas and temples
5. Statistical Interpretation	Microsoft Excel	Using statistical functions
6. Report, presentation	Word, PowerPoint	Using standard formats and fonts

4. LABORATORY TEST

The tests required for the investigation of concrete grade enhancer admixture on structural design of high rise building using reinforced concrete are compressive and flexural strength tests. For conducting such a tests there are four 50x10x10cm, two 60x15x15cm and two 75x15x15cm rectangular molds for flexural strength test with eight 15x15x15cm cubic molds for compressive strength test at Addis Ababa Science and Technology University. Having such number of molds the concrete samples casting takes four days to cast the required 64 concrete samples for the research.

Generally the laboratory test follows the following major steps;

Step 1 - Fixing test mold

Step 2 - Oiling test mold

Step 3 - Material batching

Step 4 - Concrete mixing

Step 5 - Check workability of concrete mix using slump test

Step 6 - Concrete casting and Vibrating

Step 7 - Cleaning laboratory equipment and demolishing test mold

Step 8 - Curing of concrete

Step 9 - Conducting laboratory test

- **Step 9.1** - Conducting compressive strength test
- **Step 9.2** - Conducting flexural strength test

Following the above procedures concrete mix is prepared with four different trials and a total of 64 concrete samples are casted. The mixing proportions for trial concrete mixes is given shown below.

- Trial mix type I is a concrete mix with 360 kg of cement, 600.8 kg of sand, 1154.2 kg of aggregate & 200 liter of water for 1m^3 concrete work;
- Trial mix type II is a concrete mix with 450 kg of cement, 643.16 kg of Sand, 1146.4 kg of aggregate & 195 liter of water for 1m^3 concrete work;
- Trial mix type III is a concrete mix with 360 kg of cement, 600.8 kg of Sand, 1154.2 kg of aggregate, 2% admixture by weight of cement & w/c = 0.3 for 1m^3 concrete work;
- Trial mix type IV is a concrete mix with 450 kg of cement, 643.16 kg of Sand, 1146.4 kg of aggregate, 1.5% admixture by weight of cement & w/c = 0.3 for 1m^3 concrete.

Refer appendix A for detail explanation of methods and procedures to conduct laboratory tests.

Accordingly, the laboratory test for slump, compressive and flexural strength test is conducted at the age of seven and 28 days and the following result is obtained as clearly shown on section 3.1, 3.2 and 3.2 given below.

4.1 SLUMP TEST

Slump test is conducted to check the required workability and consistence of fresh concrete using cone shaped metal cylinder with a bottom diameter of 20cm and top diameter of 10cm at a height of 30cm. In generally this test determines the easy and homogeneity with which it can be mixed, placed, compacted and furnish and serve the purpose it is intended for when hardened. The workability and consistence of fresh concrete may be affect by the amount water content, size, shape & textures of aggregate, use of admixture, mix proportions and grading of aggregate. Consider such factors, the trial mix for both type of concrete grads, C-25 & C-40 are controlled with the acceptable slump value ranges from 2-8cm according to the ACI mixing method.

Slump test conducted for all concrete mixes using the following procedure given below.

Step 1 - Take concrete mix from the discharge of the mixer;

Step 2 - Dampen concrete inside of cone and place it on a smooth, moist, non-absorbent manner

Step 3 - Fill slump cone one third full by volume and rod with 16mm diameter and 60cm long hemispherical tip steel tamping rod;

Step 4 - Fill cone 2/3 full by volume and rod with rod penetrating into, but not through first layer;

Step 5 - Fill cone to overflowing and rod with rod penetrating into, but not through, second layer by distribute rodding evenly over the entire cross section of this layer;

Step 6 - Remove the excess concrete from the top of the cone, using concrete spoon and clean overflow from base of the sump cone;

Step 7 - Immediately lift slump cone vertically with slow, even motion; invert the withdrawn cone, and place next to;

Step 8 - Lay a straight edge across the top of the slump cone and measure the amount of slump;

Following the above procedure the value of slump for all trial concrete mixes summarized as shown in the table below.

Table 4.1 Slump test result

Date	Round	Mix proportion (Kg)					Concrete Grade	Slump (Cm)	Remark
		Cement	Sand	Aggregate	Water	Admixture			
$1m^3$	1, 2, 3	360	600.8	1154.2	200	Not used	C-25	-	-
7-Mar-18	1	19.4	32.37	62.18	10.78	Not used		3.75	Ok!

Date	Round	Mix proportion (Kg)					Concrete Grade	Slump (Cm)	Remark
		Cement	Sand	Aggregate	Water	Admixture			
	2	19.4	32.37	62.18	10.78	Not used		3.73	Ok!
	3	5.4	9.01	17.3	3	Not used		3.8	Ok!
1m^3	1, 2, 3	360	600.8	1154.2	108	7.2	C-40	-	-
8-Mar-18	1	22.1	36.87	70.84	6.63	0.44		5.22	Ok!
	2	22.1	36.87	70.84	6.63	0.44		5.25	Ok!
	3	7.29	12.17	23.3	2	0.15		5.2	Ok!
1m^3	1, 2, 3	450	643.2	1146.4	195	Not used	C-25	-	-
9-Mar-18	1	24.24	34.65	61.76	10.51	Not used		4.45	Ok!
	2	24.24	34.65	61.76	10.51	Not used		4.5	Ok!
	3	4.5	6.43	11.46	1.95	Not used		4.45	Ok!
1m^3	1, 2, 3	450	643.2	1146.4	135	6.75	C-40	-	-
10-Mar-18	1	24.24	34.65	61.76	7.27	0.36		4.2	Ok!
	2	24.24	34.65	61.76	7.27	0.36		4.2	Ok!
	3	6.08	8.68	15.48	1.82	0.09		4.3	Ok!

Figure 4.1 Slump test

4.2 FLEXURAL STRENGTH TEST

The flexural strength test is conducted to know the flexural strength or modulus of rupture or bend strength of beam or to know ductility behavior of concrete. The test is employed, in which a specimen having rectangular cross-section is bent until fracture or yielding using one, two or three point loading techniques. The choice of flexural strength test types depends on various factors such as span length of specimen, availability of equipment's. For this research one point flexural strength test is used because of the available digital type of computer controlled machine called F 060 Universal Testing Machine has one point loading. Moreover the available machine is one point flexural testing machine, conducting one point flexural strength test is better to get the maximum effect on small span concrete specimens than that of two point flexural strength test. The testing machine using its digital form gives different results like maximum load, maximum deformation, maximum flexural strength, load-time graph, deformation-time graph, load-deformation graph and stress-strain graph with tables.

The test is conducted at concrete ages of seven and twenty eight days and the following result is obtained as shown given below on section 4.2.1 and 4.2.2.

4.2.1 SEVEN DAYS FLEXURAL STRENGTH TEST RESULT

<u>Sample 1 flexural strength test result for C-25 concrete (Size 50x10x10 cm)</u>

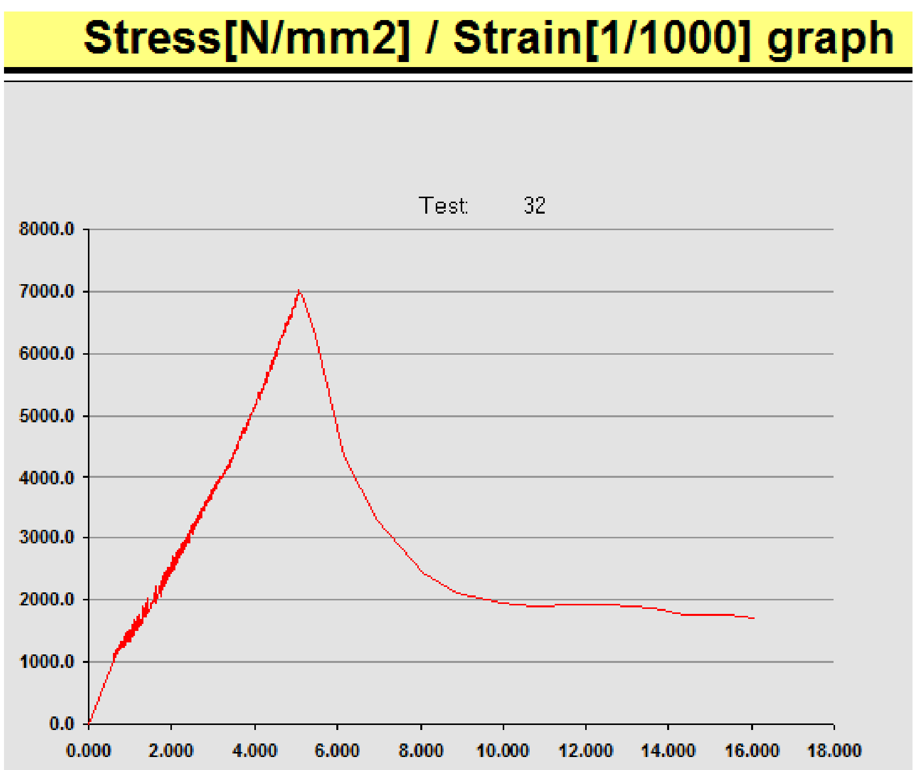


Figure 4.2 Stress-Strain curve for sample 1 with C-25 concrete

Sample 2 flexural strength test result for C-25 concrete (Size 50x10x10 cm)

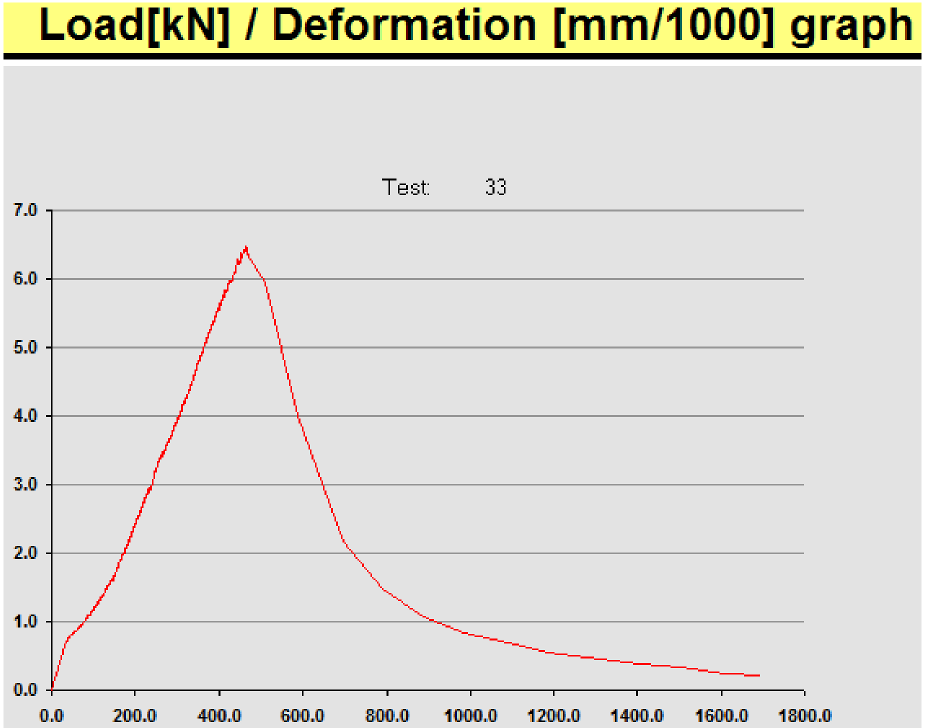


Figure 4.3 Load-Deformation curve for sample 2 with C-25 concrete

Sample 3 flexural strength test result for C-25 concrete (Size 50x10x10 cm)

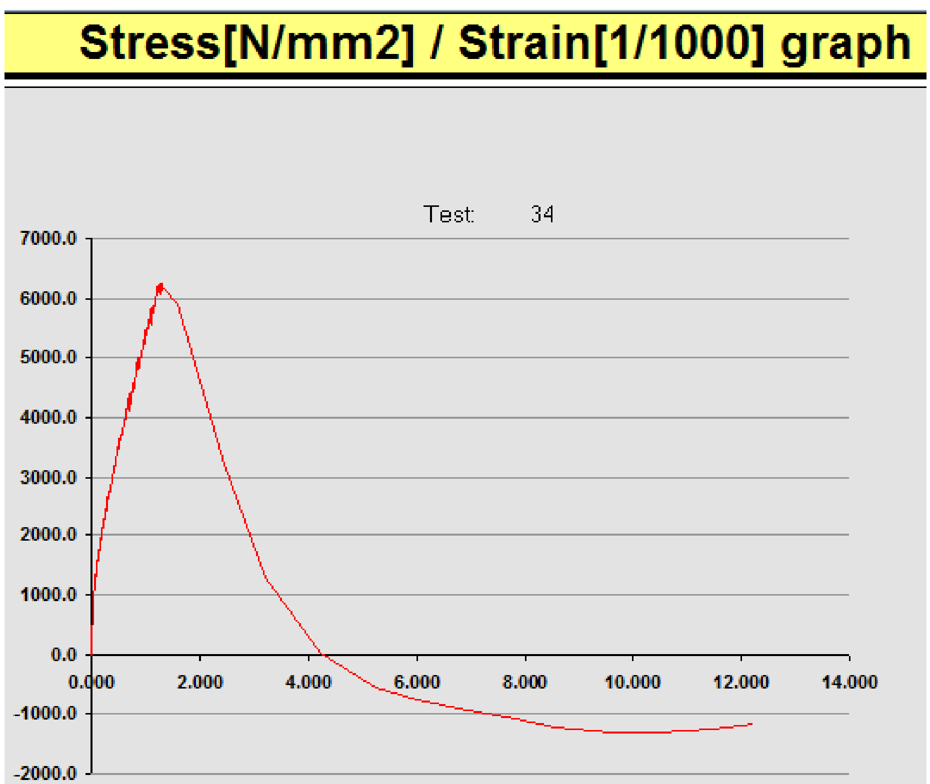


Figure 4.4 Stress-Strain curve for sample 3 with C-25 concrete

Sample 4 flexural strength test result for C-25 concrete (Size 50x10x10 cm)

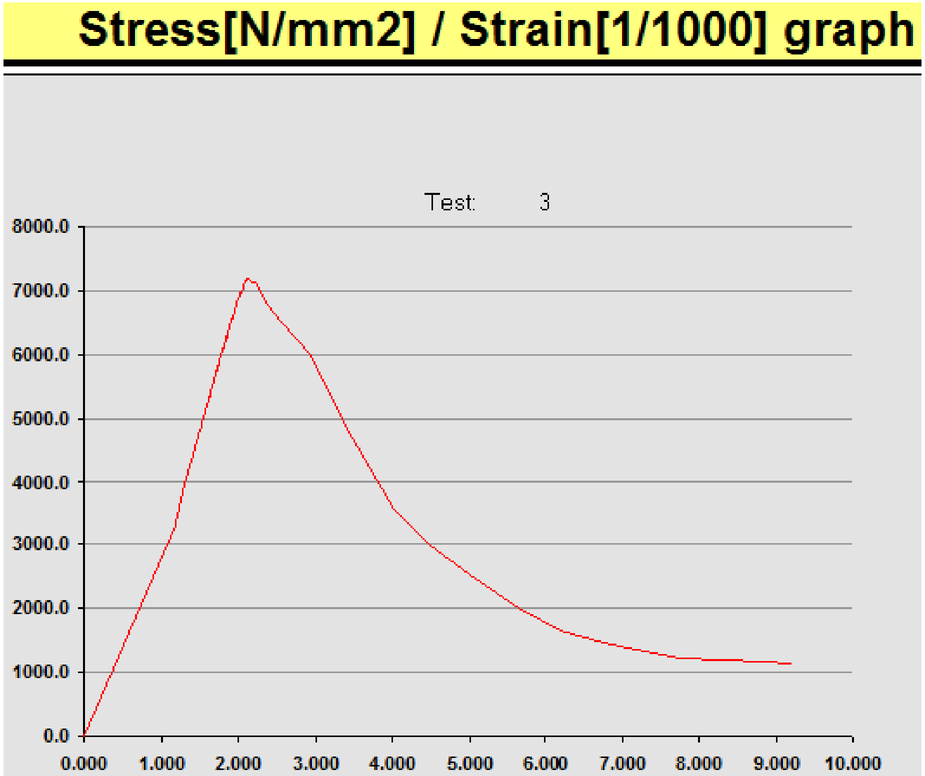


Figure 4.5 Stress-Strain curve for sample 4 with C-25 concrete

Sample 5 flexural strength test result for C-25 concrete (Size 60x15x15 cm)

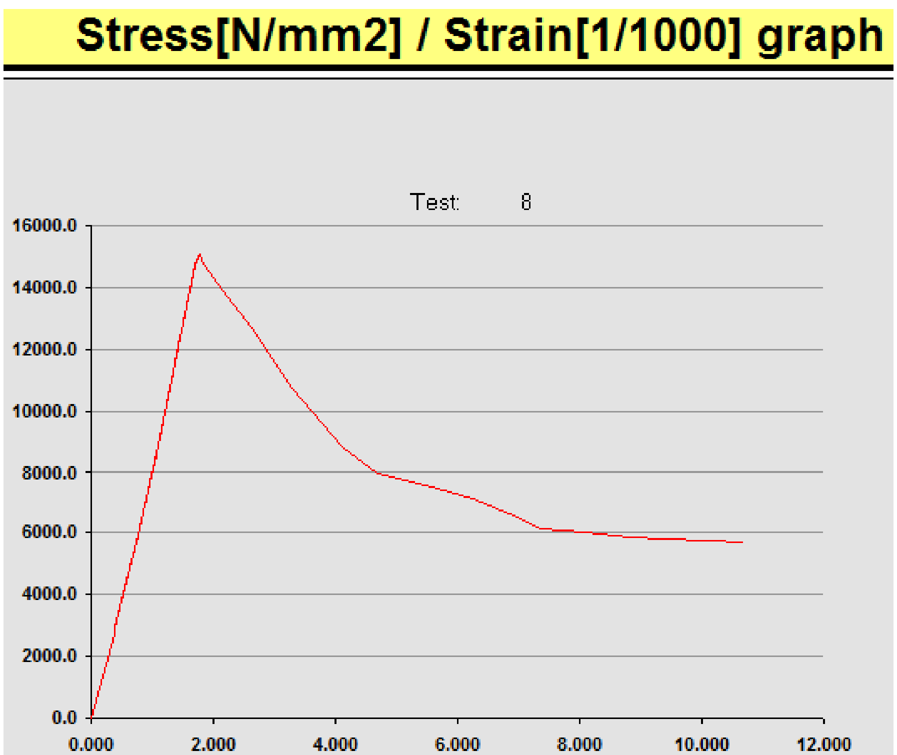


Figure 4.6 Stress-Strain curve for sample 5 with C-25 concrete

Sample 6 flexural strength test result for C-25 concrete (Size 60x15x15 cm)

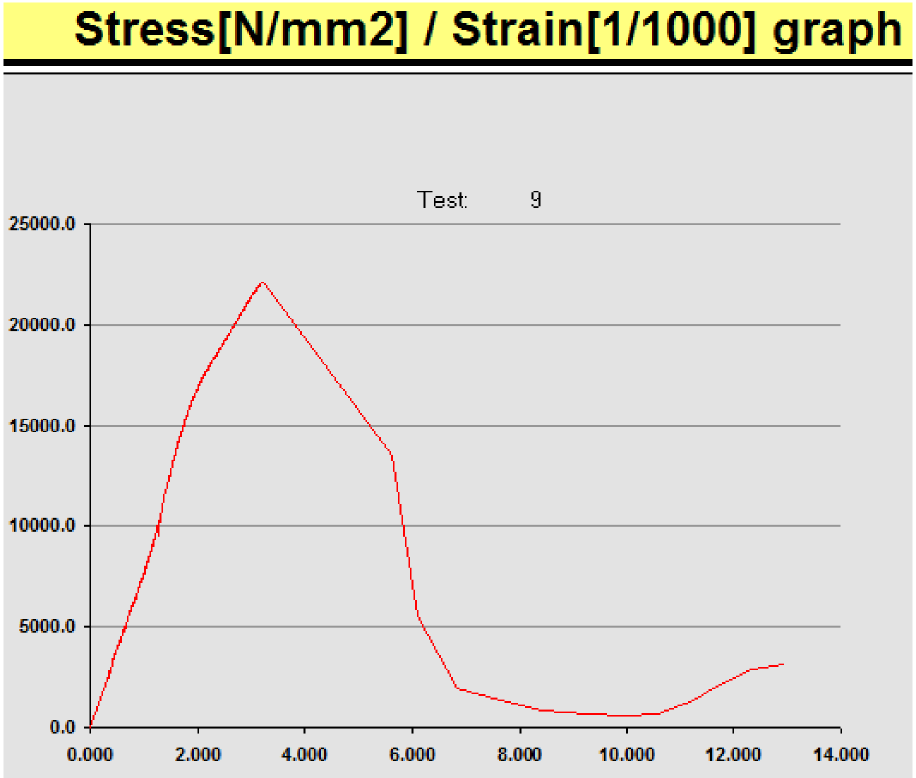


Figure 4.7 Stress-Strain curve for sample 6 with C-25 concrete

Sample 7 flexural strength test result for C-25 concrete (Size 75x15x15 cm)

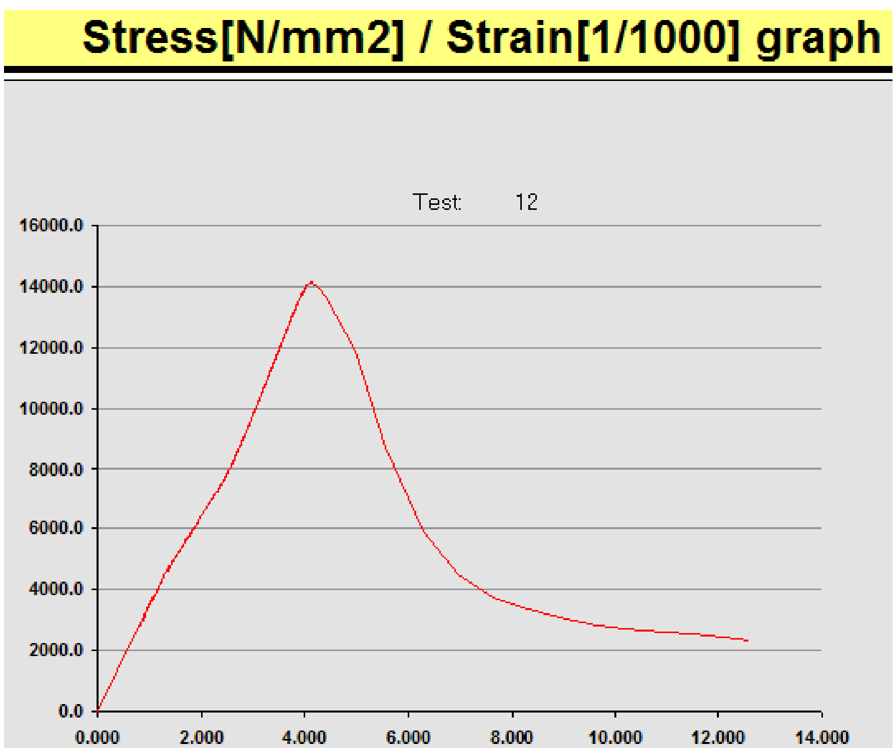


Figure 4.8 Stress-Strain curve for sample 7 with C-25 concrete

Sample 8 flexural strength test result for C-25 concrete (Size 75x15x15 cm)

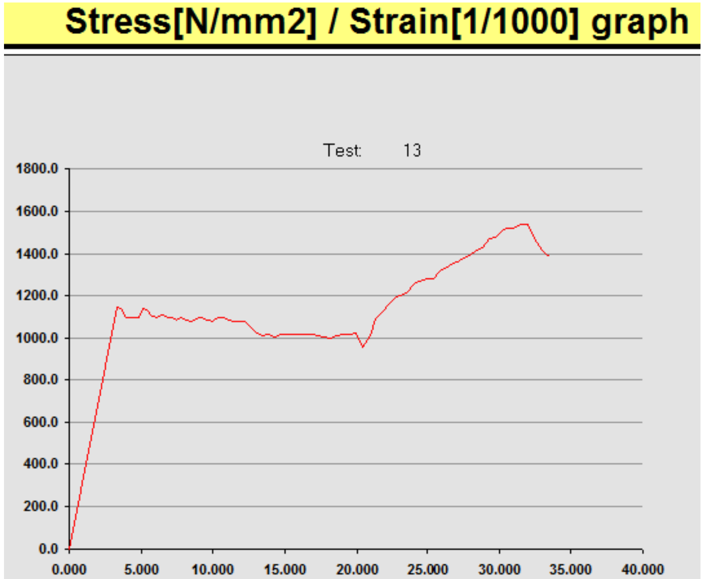


Figure 4.9 Stress-Strain curve for sample 8 with C-25 concrete

Remark 4.1 Sample 8 was damaged by machine during adjusting the daylight between the sample and the central bearer.

Sample 1 flexural strength test result for C-40 concrete (Size 50x10x10 cm**)**

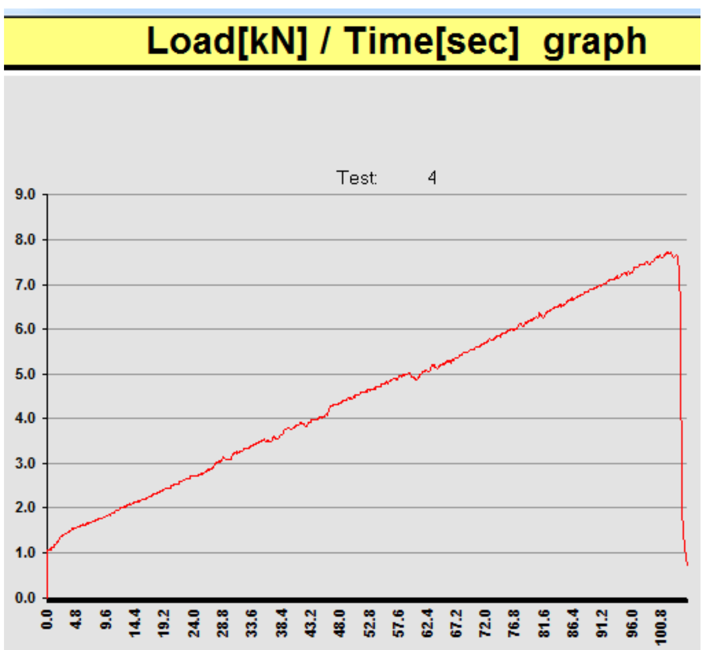


Figure 4.10 Load-Time curve for sample 1 with C-40 concrete

Remark 4.2 The machine may give unreliable result like the graph shown in figure 3-33 if their inadequate electric power to run the machine or due the present of large daylight between the sample and bearer.

<u>Sample 2 flexural strength test result for C-40 concrete (Size 50x10x10 cm)</u>

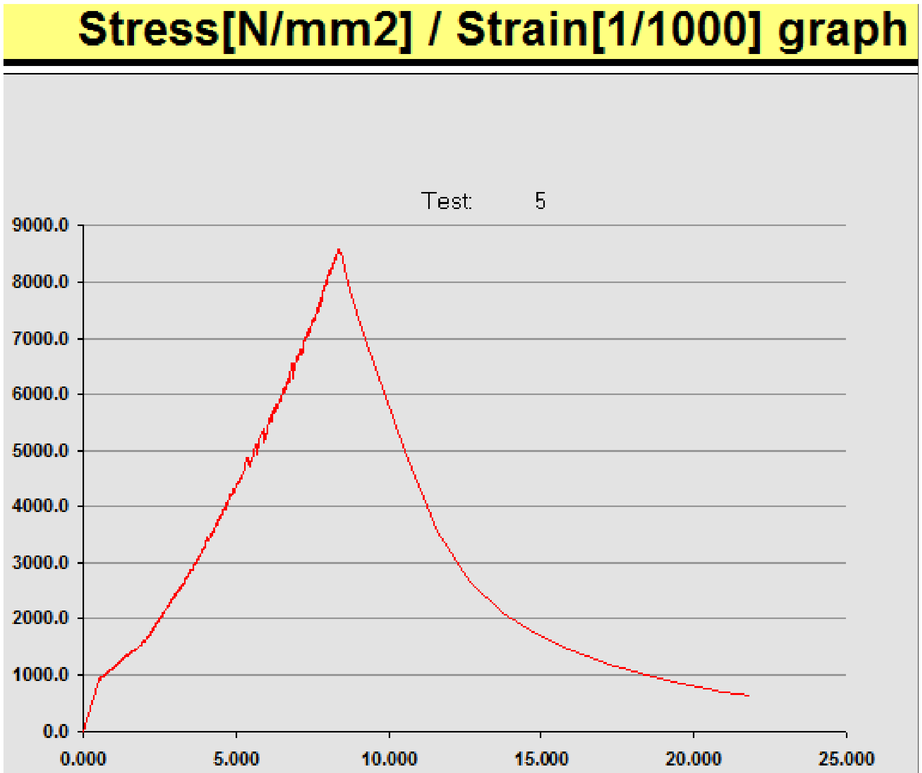


Figure 4.11 Stress-Strain curve for sample 2 with C-40 concrete

<u>Sample 3 flexural strength test result for C-40 concrete (Size 50x10x10 cm)</u>

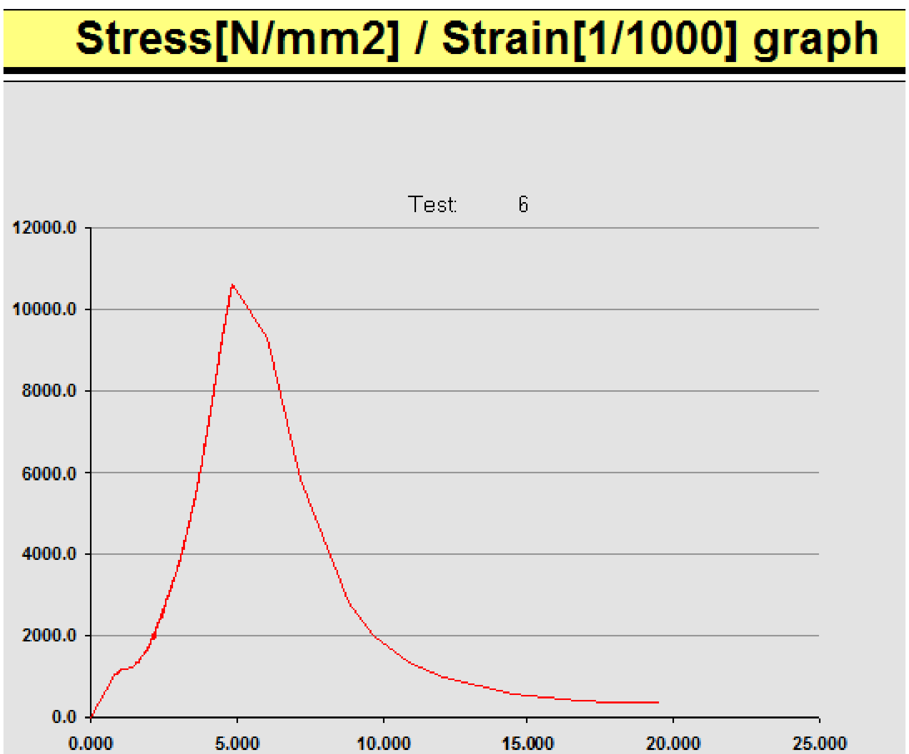


Figure 4.12 Stress-Strain curve for sample 3 with C-40 concrete

Sample 4 flexural strength test result for C-40 concrete (Size 50x10x10 cm)

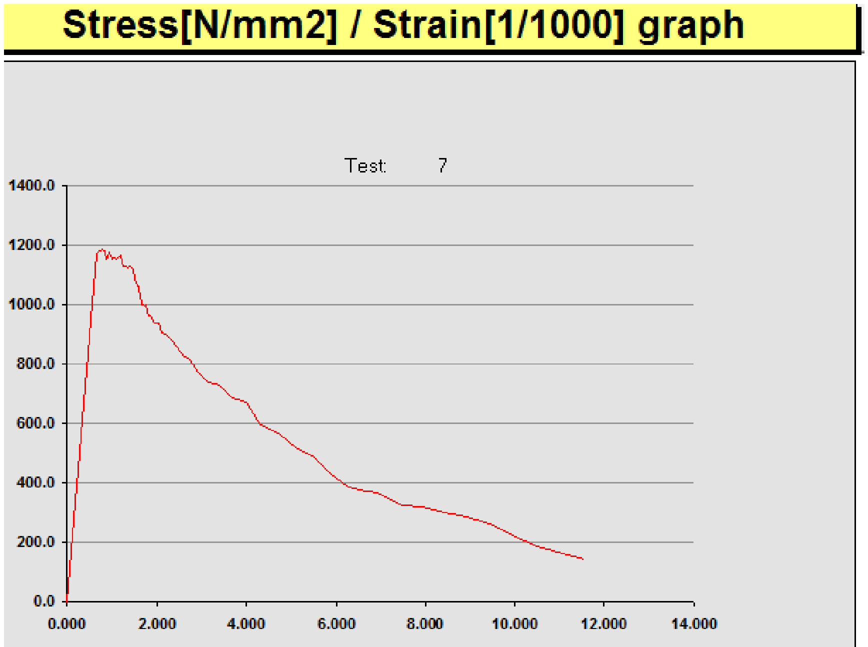


Figure 4.13 Stress-Strain curve for sample 4 with C-40 concrete

<u>Remark 4.3</u> Sample 4 was damaged by machine during adjusting the daylight between the sample and the central bearer.

Sample 5 flexural strength test result for C-40 concrete (Size 60x15x15 cm)

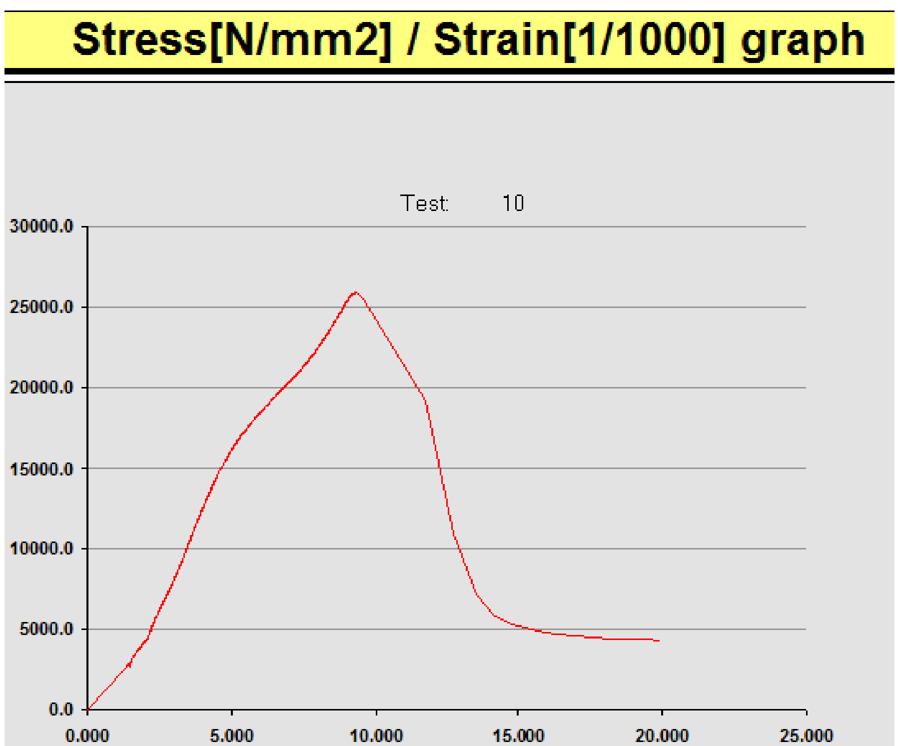


Figure 4.14 Stress-Strain curve for sample 5 with C-40 concrete

Sample 6 flexural strength test result for C-40 concrete (Size 60x15x15 cm)

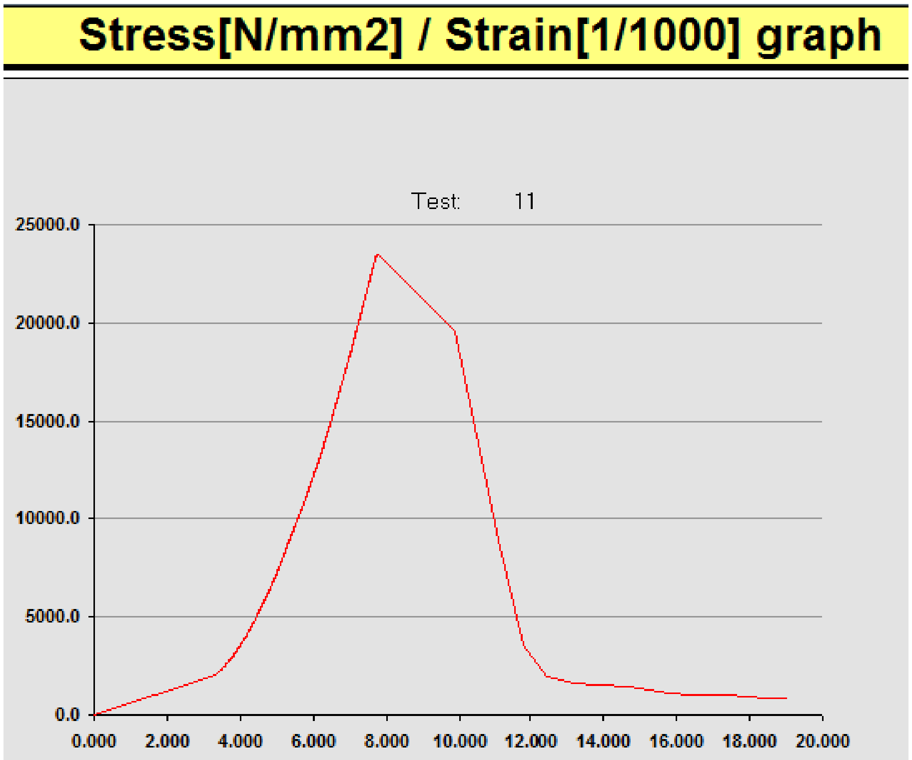


Figure 4.15 Stress-Strain curve for sample 6 with C-40 concrete

Sample 7 flexural strength test result for C-40 concrete (Size 75x15x15 cm)

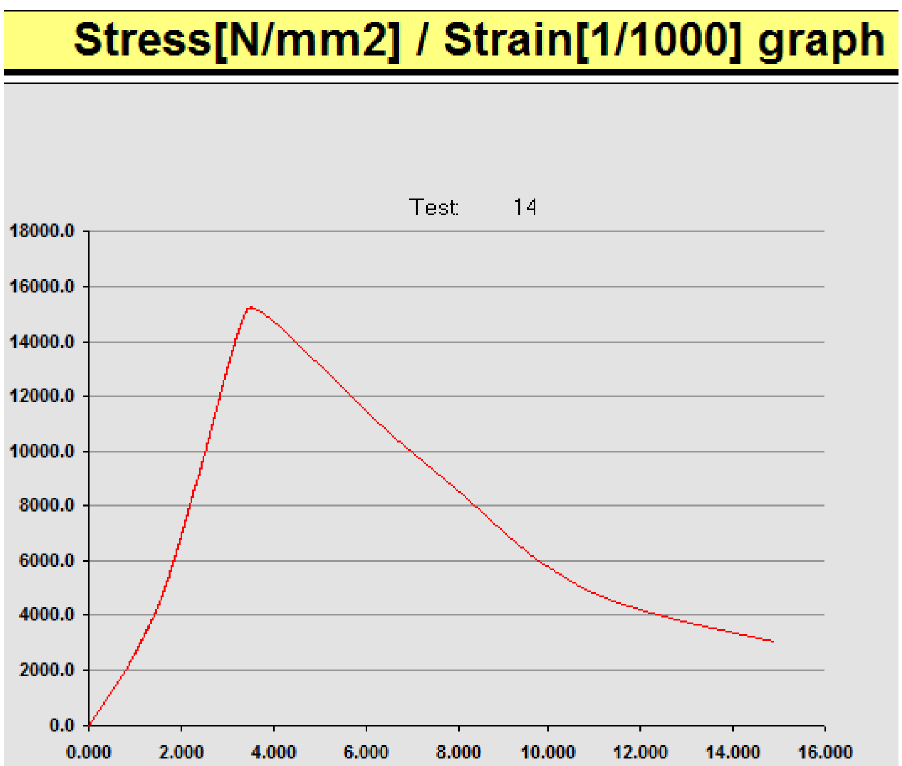


Figure 4.16 Stress-Strain curve for sample 7 with C-40 concrete

Sample 8 flexural strength test result for C-40 concrete (Size 75x15x15 cm)

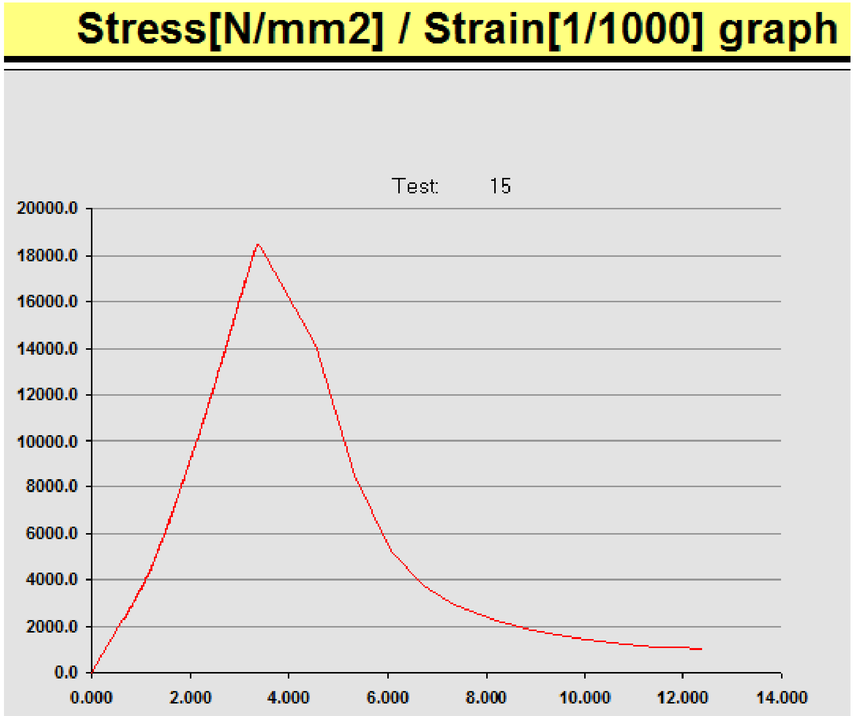


Figure 4.17 Stress-Strain curve for sample 8 with C-40 concrete

Moreover, the test results given above in graphical form, flexural strength test results at the age of seven days summarized as shown in the table given below.

Table 4.2 Seven days flexural strength test result

Sample No	**Date of casted**	**Date of tasted**	**Dimension (cm)**	**Max Load (KN)**	**Max Def. (mm)**	**Flexural strength (mpa)**	**Concrete Grade**
360 kg of cement, 600.8 kg of Sand, 1154.2 kg of aggregate & 200 liter of water for 1m^3 concrete work							
1	7-Mar-18	17-Mar-18	50x10x10	7.04	1.61148	5.28	C-25
2			50x10x11	6.48	1.69522	4.86	
5			60x15x15	15.06	1.6023	4.016	
7			75x15x15	14.16	1.88964	3.776	
					Average	**4.483**	
450 kg of cement, 643.16 kg of Sand, 1146.4 kg of aggregate & 195 liter of water for 1m^3 concrete							
3	9-Mar-18	17-Mar-18	50x10x10	6.260	1.223	4.695	C-25
4			50x10x11	6.260	1.223	4.695	
6			60x1s5x15	22.100	1.943	5.893	
8			75x15x15	14.160	1.890	3.776	
					Average	**4.765**	
360 kg of cement, 600.8 kg of Sand, 1154.2 kg of aggregate, 2% admixture by weight of cement & w/c = 0.3 for 1m^3 concrete							
1	8-Mar-18	17-Mar-18	50x10x10	7.720	0.190	5.790	C-40

Sample No	Date of casted	Date of tasted	Dimension (cm)	Max Load (KN)	Max Def. (mm)	Flexural strength (mpa)	Concrete Grade
2			50x10x11	8.560	2.184	6.420	
5			60x15x15	25.920	2.989	6.912	
7			75x15x15	15.260	2.236	5.087	
					Average	**6.052**	
450 kg of cement, 643.16 kg of Sand, 1146.4 kg of aggregate, 1.5% admixture by weight of cement & w/c = 0.3 for 1m^3 concrete							
3	10-Mar-18	17-Mar-18	50x10x10	10.640	1.951	7.980	C-40
4			50x10x11	10.640	1.951	7.980	
6			60x15x15	23.460	2.855	6.256	
8			75x15x15	18.480	1.860	6.160	
					Average	**7.094**	

Remark 4.4 The flexural strength of damaged samples (i.e sample no 4 & 8 for C-25 concrete, sample no 4 for C-40) by machine during adjusting the daylight between the sample and the central bearer was taken as the same value as similar tests values.

4.2.2 TWENTY EIGHTH DAYS FLEXURAL STRENGTH TEST RESULT

Sample 9 flexural strength test result for C-25 concrete (Size 75x15x15 cm)

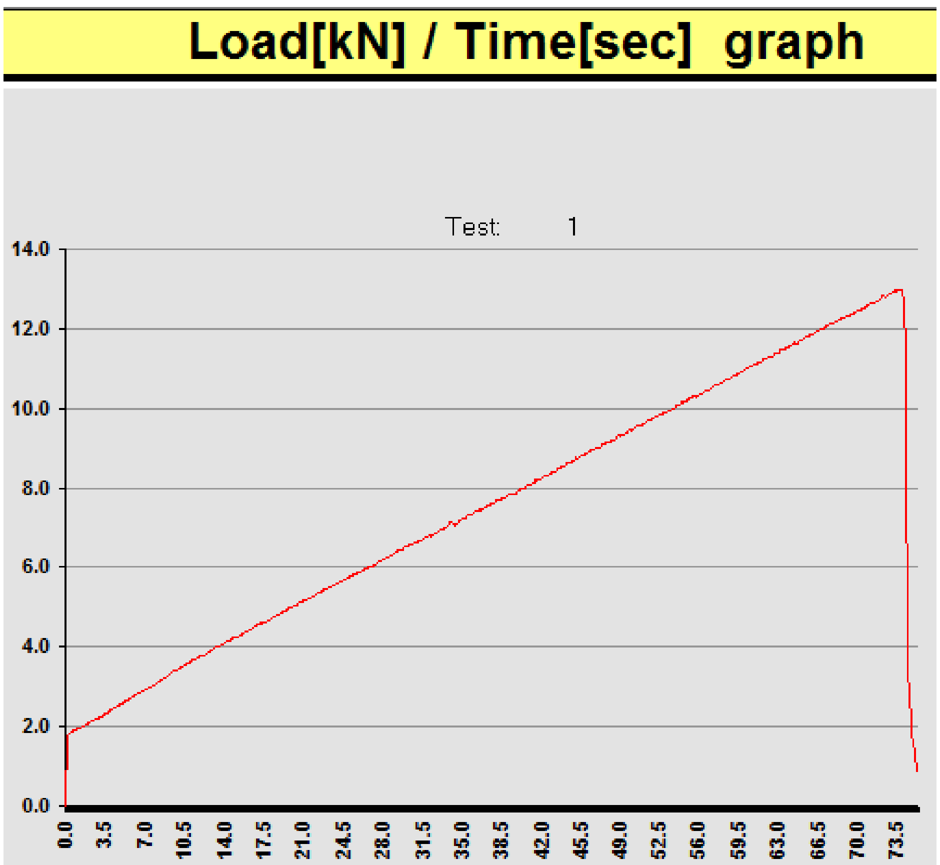


Figure 4.18 Load-Time curve for sample 9 with C-25 concrete

Sample 10 flexural strength test result for C-25 concrete (Size 75x15x15 cm)

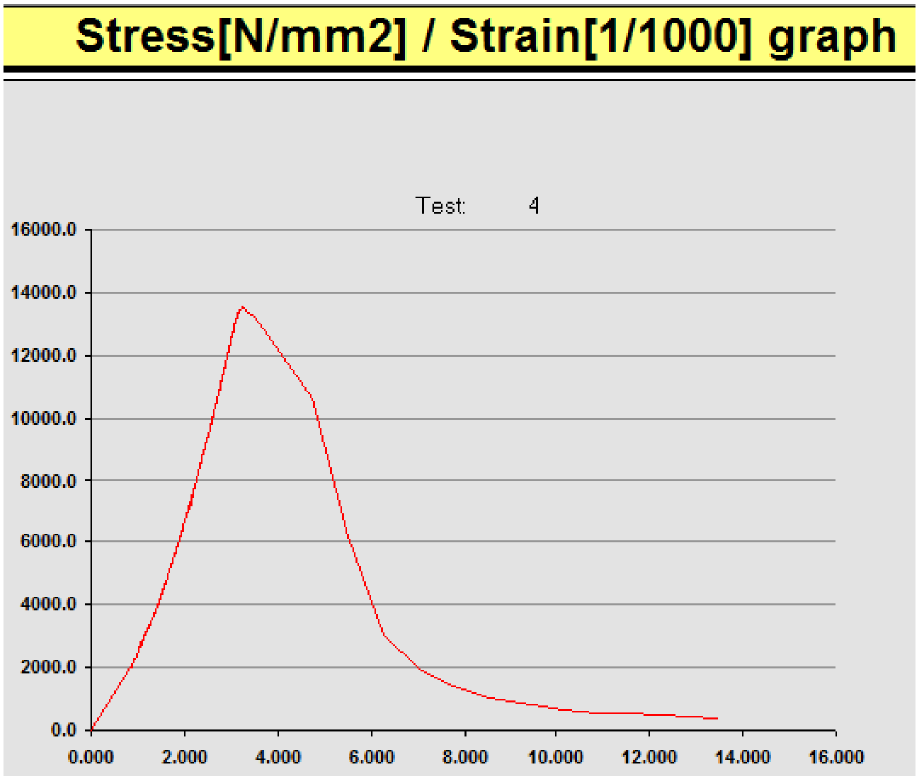


Figure 4.19 Stress-Strain curve for sample 10 with C-25 concrete

Sample 11 flexural strength test result for C-25 concrete (Size 60x15x15 cm)

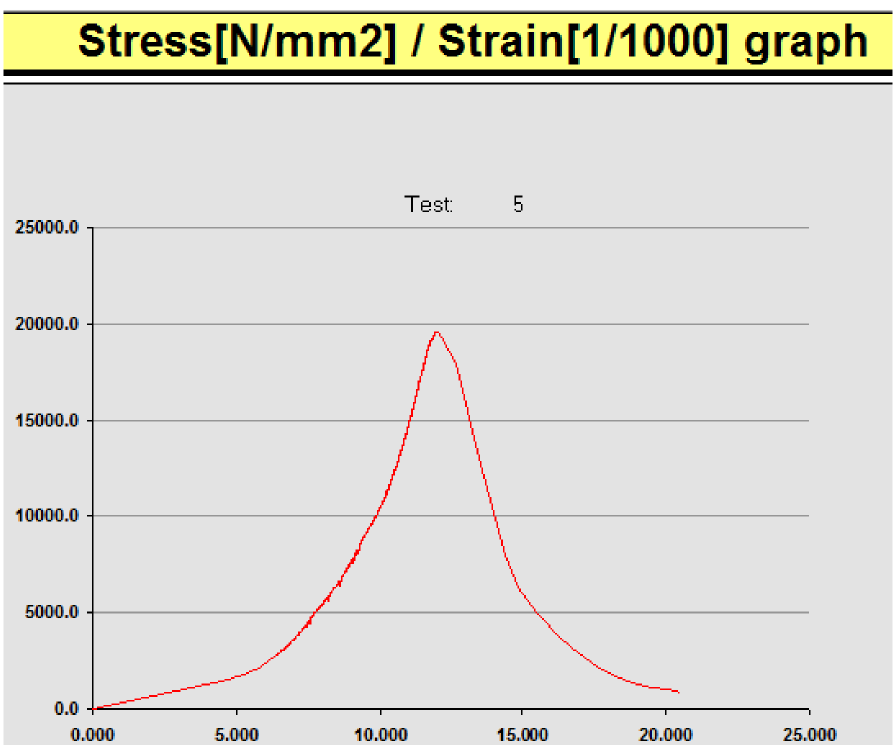


Figure 4.20 Stress-Strain curve for sample 11 with C-25 concrete

Sample 12 flexural strength test result for C-25 concrete (Size 60x15x15 cm)

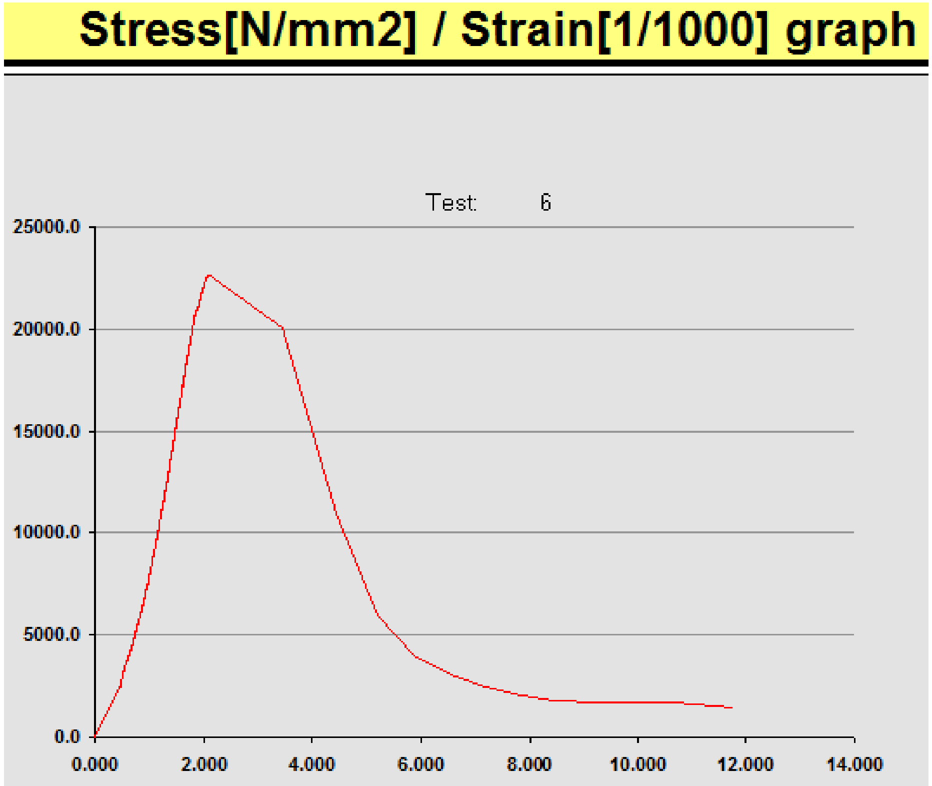


Figure 4.21 Stress-Strain curve for sample 12 with C-25 concrete

Remark 4.5 Sample 13 was damaged during loading to testing machine.

Sample 14 flexural strength test result for C-25 concrete (Size 50x10x10 cm)

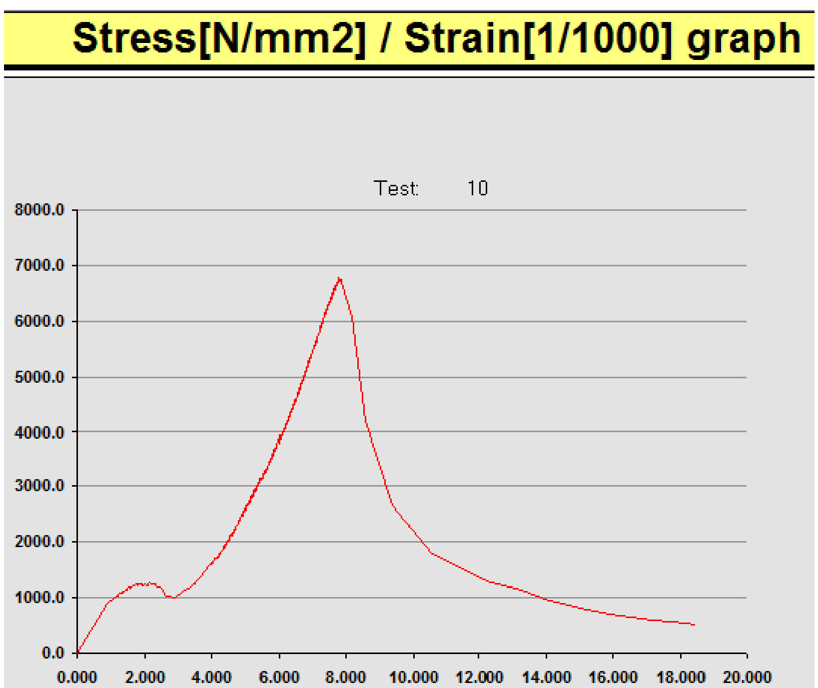


Figure 4.22 Stress-Strain curve for sample 14 with C-25 concrete

Sample 15 flexural strength test result for C-25 concrete (Size 50x10x10 cm)

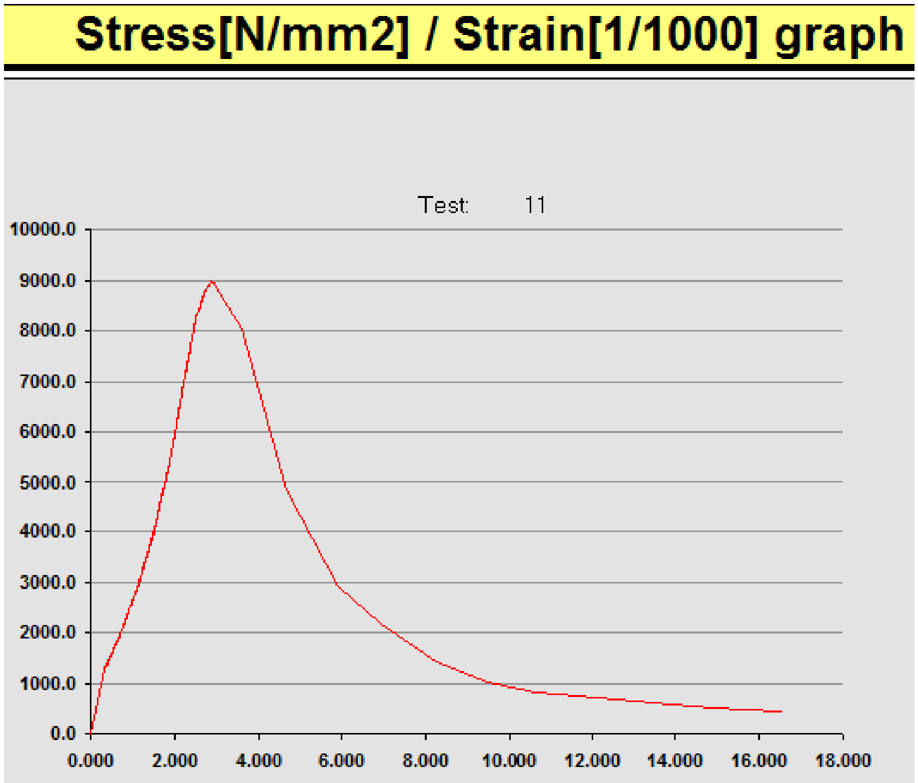


Figure 4.23 Stress-Strain curve for sample 15 with C-25 concrete

Sample 16 flexural strength test result for C-25 concrete (Size 50x10x10 cm)

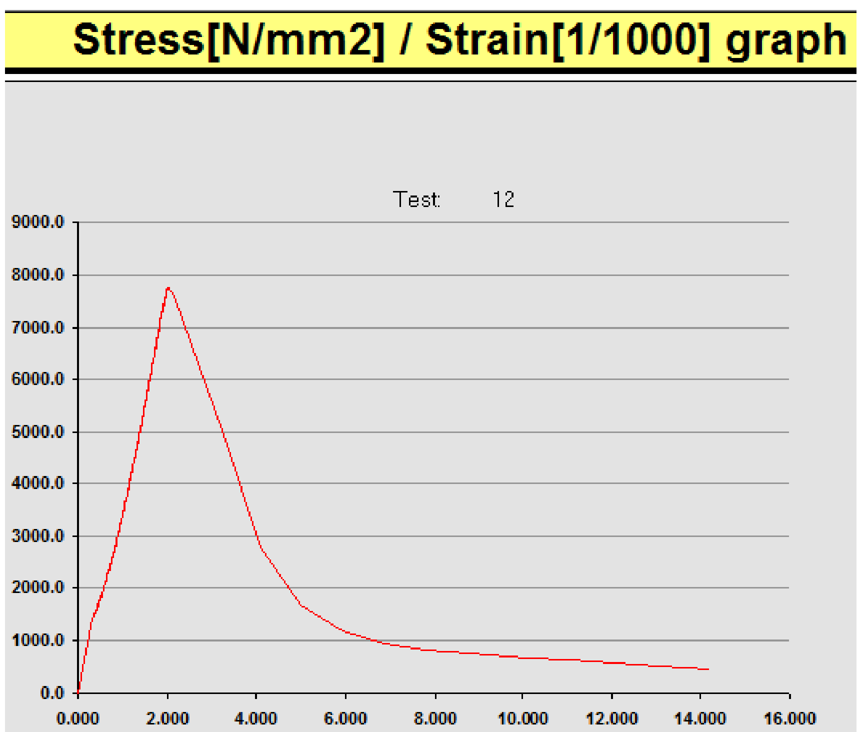


Figure 4.24 Stress-Strain curve for sample 16 with C-25 concrete

Sample 9 flexural strength test result for C-40 concrete (Size 75x15x15 cm)

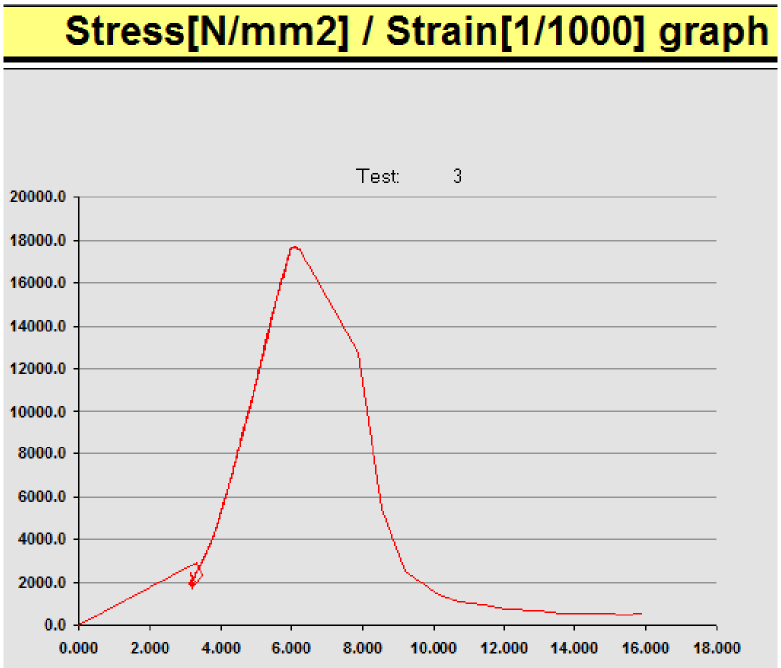


Figure 4.25 Stress-Strain curve for sample 9 with C-40 concrete

Remark 4.6 The graphical result of sample 10 has been lost during error in sniping the test result from the Tecnotest software. However, the test result for sample 10 is obtained in Tecnotest database in tabular form and given in table 3.3.

Sample 11 flexural strength test result for C-40 concrete (Size 60x15x15 cm)

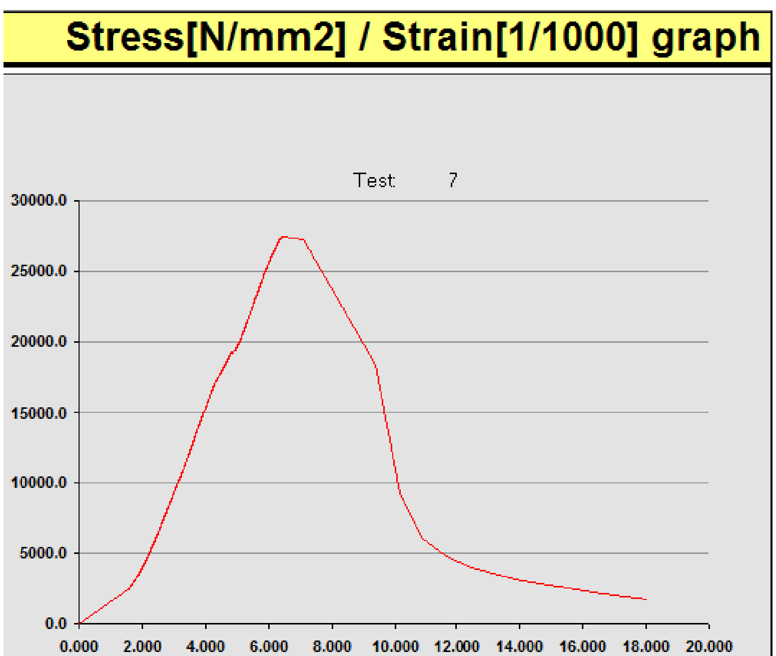


Figure 4.26 Stress-Strain curve for sample 11 with C-40 concrete

Sample 12 flexural strength test result for C-40 concrete (Size 60x15x15 cm)

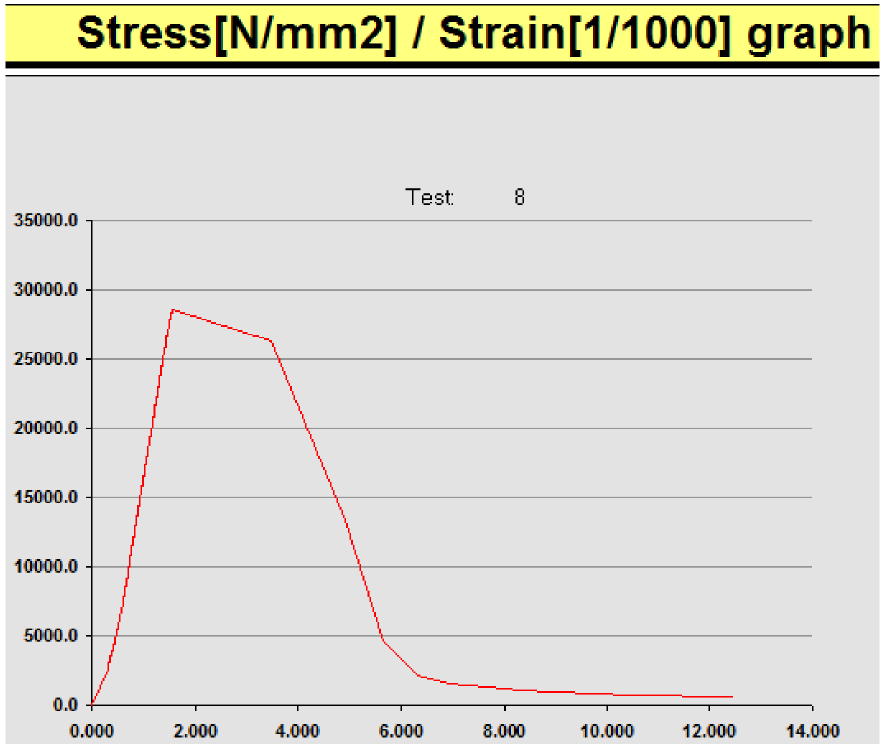


Figure 4.27 Stress-Strain curve for sample 12 with C-40 concrete

Sample 13 flexural strength test result for C-40 concrete (Size 50x10x10 cm)

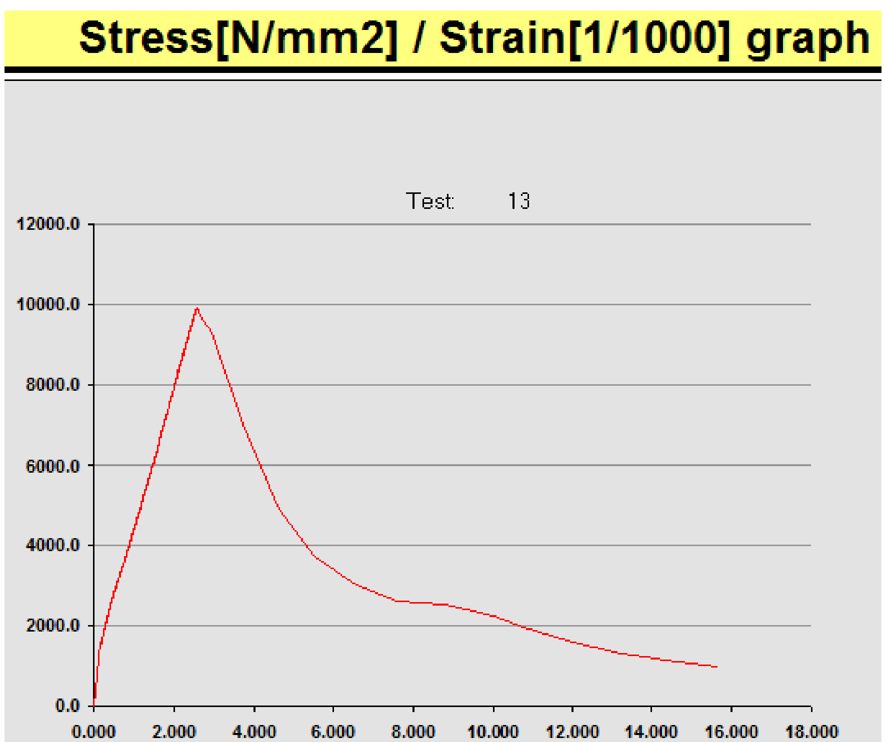


Figure 4.28 Stress-Strain curve for sample 13 with C-40 concrete

Sample 14 flexural strength test result for C-40 concrete (Size 50x10x10 cm)

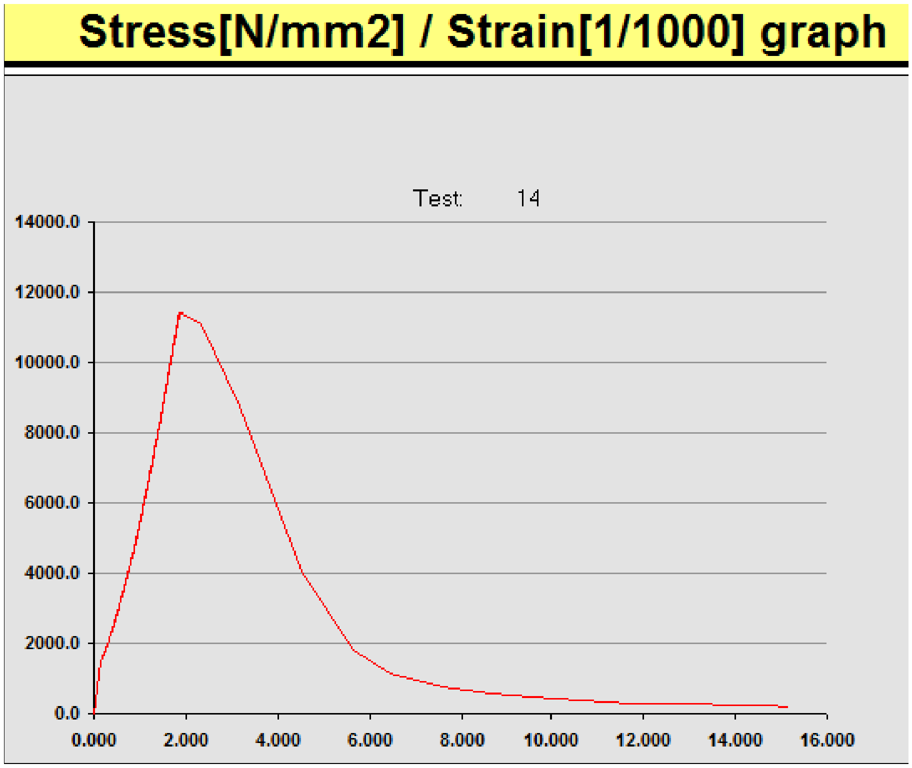


Figure 4.29 Stress-Strain curve for sample 14 with C-40 concrete

Sample 15 flexural strength test result for C-40 concrete (Size 50x10x10 cm)

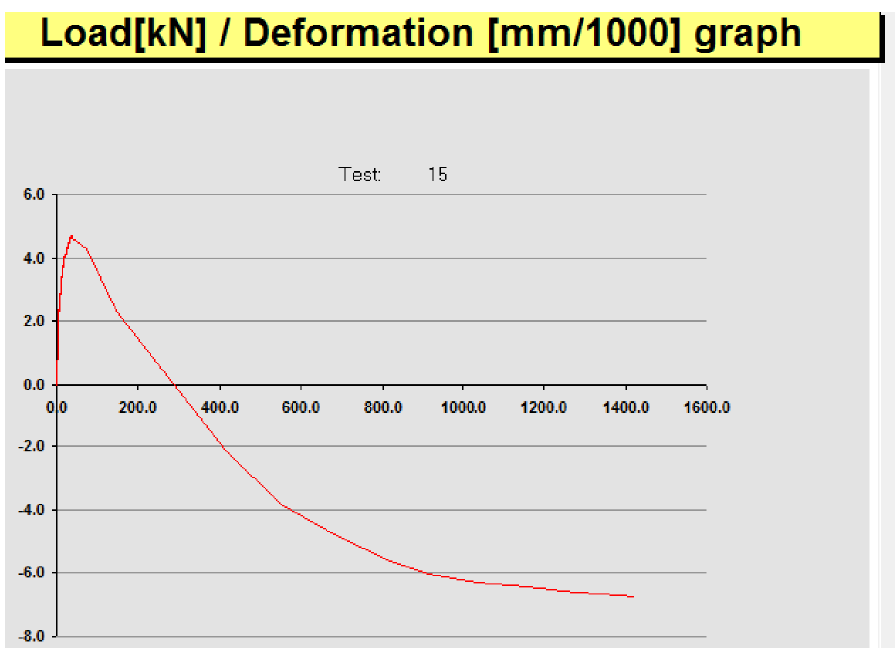


Figure 4.30 Load-Deformation curve for sample 15 with C-40 concrete

Remark 4.7 Sample 15 was damaged by machine during adjusting the daylight between the sample and the central bearer after running.

Sample 16 flexural strength test result for C-40 concrete (Size 50x10x10 cm)

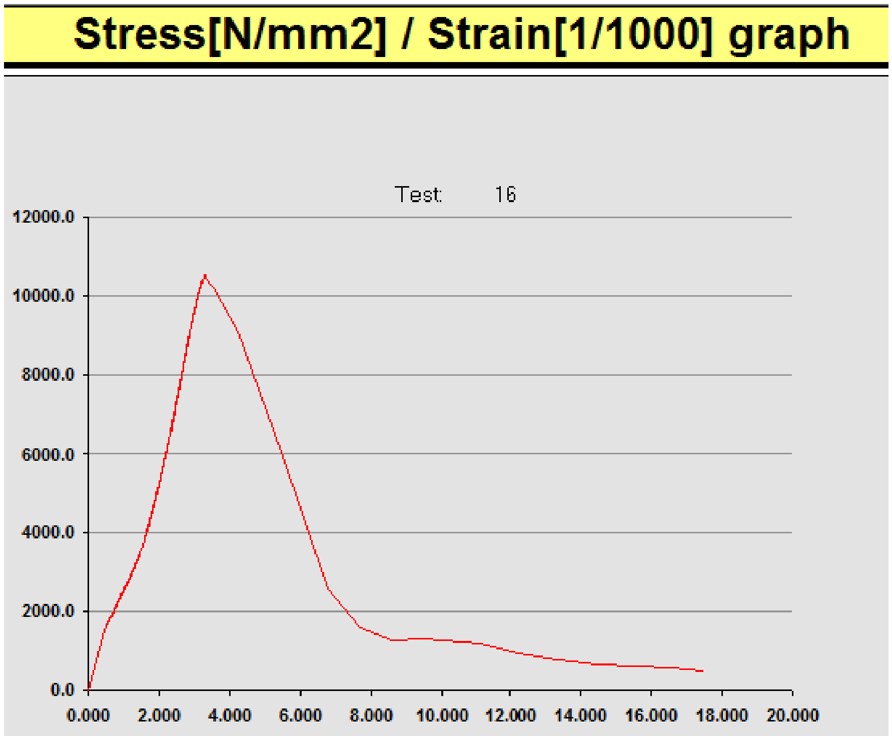


Figure 4.31 Stress-Strain curve for sample 16 with C-40 concrete

Moreover, the test results given above in graphical form, flexural strength test results at the age of twenty days summarized as shown in the table given below.

Table 4.3 Twenty days flexural strength test result

Sample No	**Date of casted**	**Date of tasted**	**Dimension (cm)**	**Max Load (KN)**	**Max Deflection (mm)**	**Flexural strength (mpa)**	**Concrete Grade**
360 kg of cement, 600.8 kg of Sand, 1154.2 kg of aggregate & 200 liter of water for 1m^3 concrete work							
9	7-Mar-18	6-Apr-18	75x15x15	13	0.00021	4.333	C-25
11			60x15x15	19.62	3.071	5.232	
13			50x10x10	6.78	1.8458	5.085	
14			50x10x10	6.78	1.8458	5.085	
					Average	**4.934**	
450 kg of cement, 643.16 kg of Sand, 1146.4 kg of aggregate & 195 liter of water for 1m^3 concrete							
10	9-Mar-18	6-Apr-18	75x15x15	13.560	2.022	4.520	C-25
12			60x15x15	22.660	1.765	6.043	
15			50x10x10	8.980	1.654	6.735	
16			50x10x10	7.780	2.421	5.835	
					Average	**5.783**	
360 kg of cement, 600.8 kg of Sand, 1154.2 kg of aggregate, 2% admixture by weight of cement & w/c = 0.3 for 1m^3 concrete							

Sample No	Date of casted	Date of tasted	Dimension (cm)	Max Load (KN)	Max Deflection (mm)	Flexural strength (mpa)	Concrete Grade
9	8-Mar-18	6-Apr-18	75x15x15	17.760	2.384	5.920	C-40
11			60x15x15	27.480	2.703	7.328	
13			50x10x10	9.960	1.564	7.470	
15			50x10x10	9.960	1.564	7.470	
					Average	**7.047**	
450 kg of cement, 643.16 kg of Sand, 1146.4 kg of aggregate, 1.5% admixture by weight of cement & w/c = 0.3 for 1m^3 concrete							
10	10-Mar-18	6-Apr-18	75x15x15	17.500	2.441	5.833	C-40
12			60x15x15	28.660	1.872	7.643	
14			50x10x10	11.600	1.517	8.595	
16			50x10x10	10.560	1.751	7.920	
					Average	**7.498**	

Remark 4.8 The flexural strength of damaged samples (i.e sample no 13 for C-25 concrete, sample no 15 for C-40) by machine during adjusting the daylight between the sample and loading was taken as the same value as similar tests values.

4.3 COMPRESSIVE STRENGTH TEST

The compressive strength is conducted to know the compressive strength of concrete using cubic concrete samples. It helps to know the mixing proportion of concrete ingredients to get C-25 and C-40 concrete grads. Moreover, it also used to know the amount of concrete grade enhancer admixture added on C-25 mixing proportions to get C-40 concrete.

4.3.1 SEVEN DAYS COMPRESSIVE STRENGTH TEST RESULT

Remark 4.9 The test result for compressive strength test using F 060 Universal Testing Machine is not look like correct. The reason for incorrect test result for compression test may be due to some problem on the machine or lack of skill or may be due to a little movement of the ball seated platen. Because of this, repeatedly measures with possible trials were made to fix the machine problem but it cannot be solved. Following this, t7he machine to conduct compressive strength test is changed from “F 060 Universal Testing Machine” to “Compression Testing Machine”.

Accordingly, the compressive strength test is conducted using Compression Testing Machine and the following result is obtained in graphical form from scan of machine print output.

Remark 4.10 The value of sample 1 is incorrect due improper use of platen type (due to use fixed platen).

Sample 2 compressive strength test result for C-25 concrete (Size 15x15x15 cm)

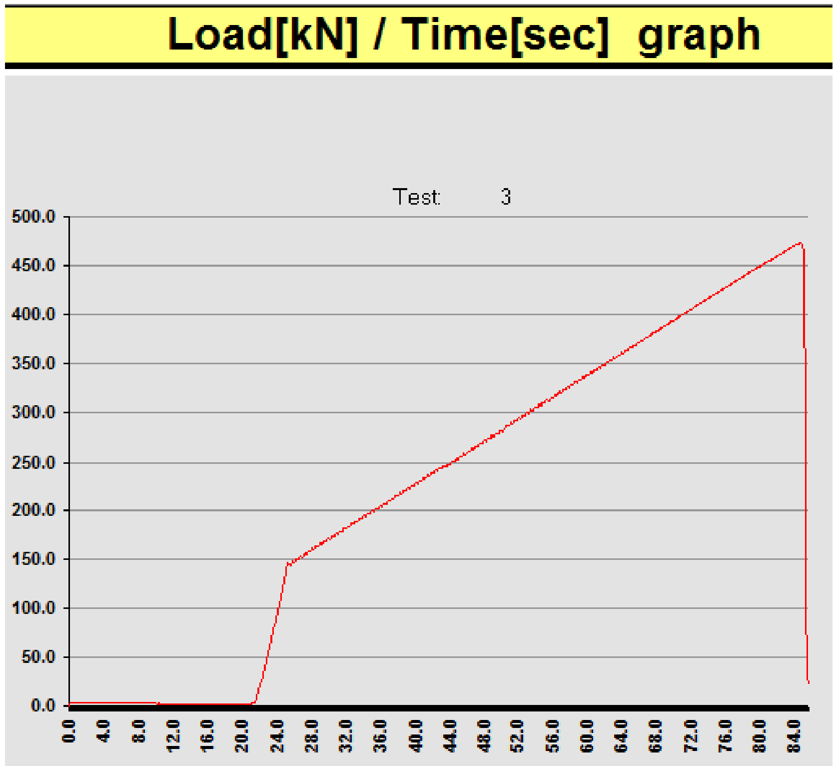


Figure 4.32 Load-Time curve for sample 2 with C-25 concrete

Sample 3 compressive strength test result for C-25 concrete (Size 15x15x15 cm)

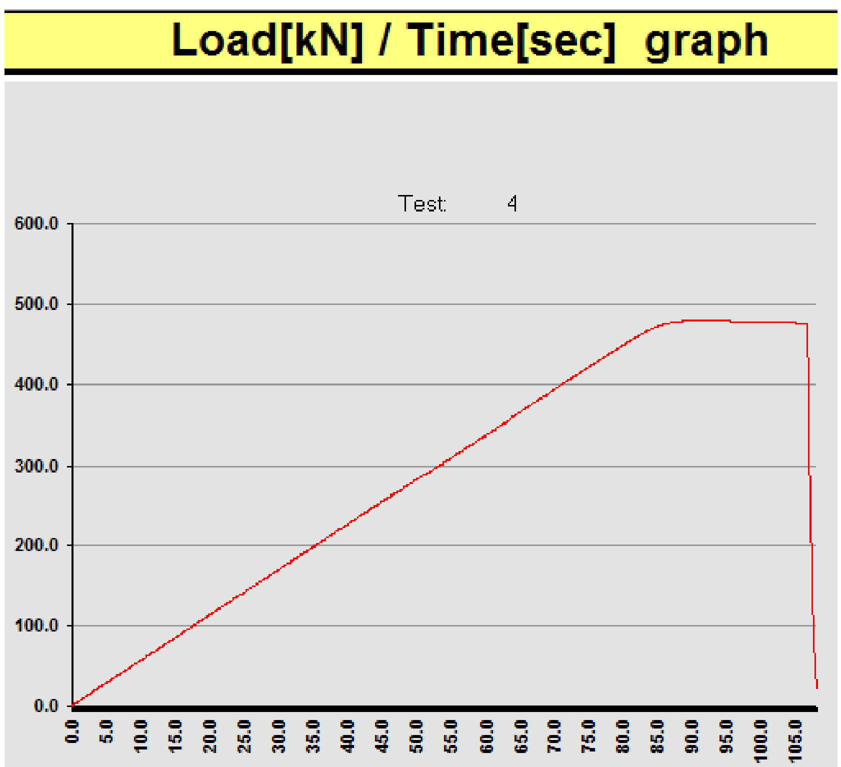


Figure 4.33 Load-Time curve for sample 3 with C-25 concrete

Sample 4 compressive strength test result for C-25 concrete (Size 15x15x15 cm)

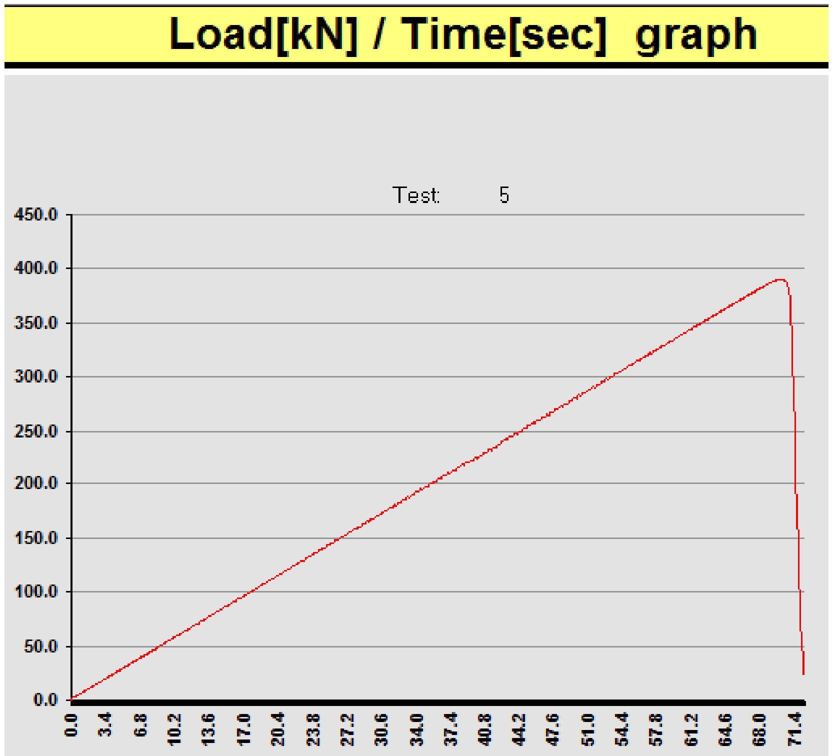


Figure 4.34 Load-Time curve for sample 4 with C-25 concrete

Sample 1 compressive strength test result for C-40 concrete (Size 15x15x15 cm)

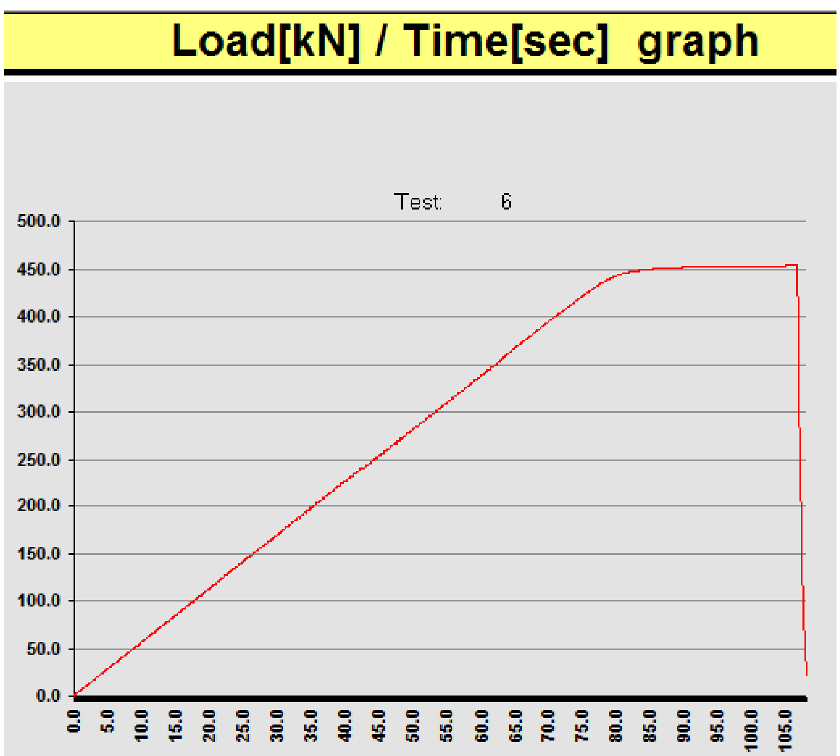
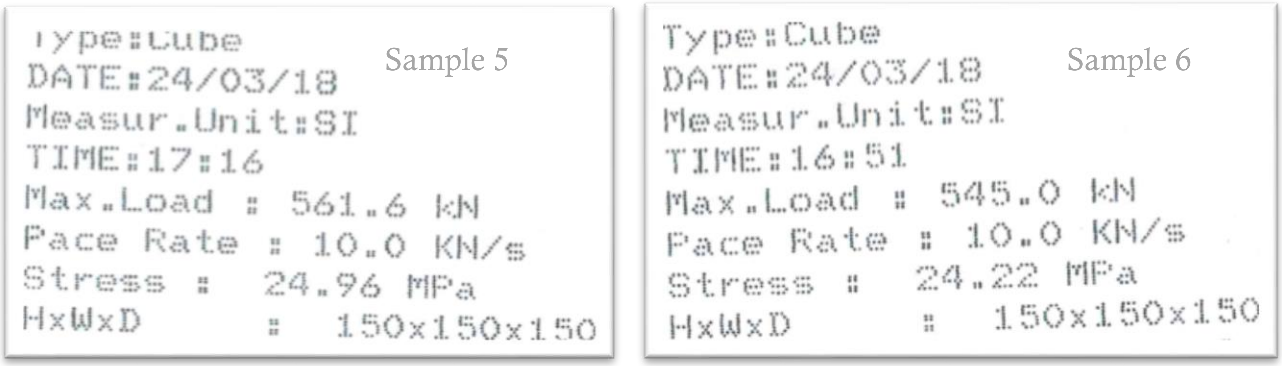


Figure 4.35 Load-Time curve for sample 1 with C-40 concrete

<u>Sample 5 & 6 compressive strength test result for C-25 concrete (Size 15x15x15 cm)</u>



Sample 5

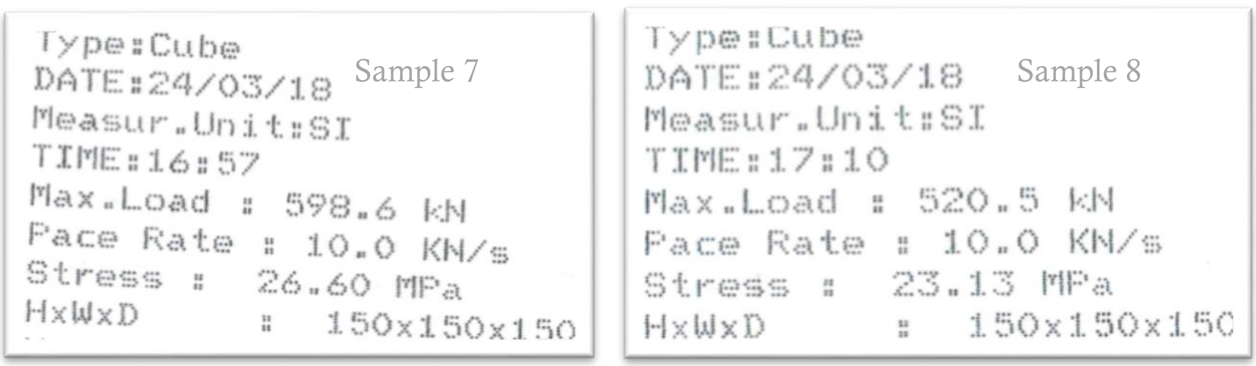
Type:Cube
DATE:24/03/18
Measur.Unit:SI
TIME:17:16
Max.Load : 561.6 kN
Pace Rate : 10.0 KN/s
Stress : 24.96 MPa
HxWxD : 150x150x150

Sample 6

Type:Cube
DATE:24/03/18
Measur.Unit:SI
TIME:16:51
Max.Load : 545.0 kN
Pace Rate : 10.0 KN/s
Stress : 24.22 MPa
HxWxD : 150x150x150

Figure 4.36 Sample 5 & 6 compressive strength test result for C-25 concrete

<u>Sample 7 & 8 compressive strength test result for C-25 concrete (Size 15x15x15 cm)</u>



Sample 7

Type:Cube
DATE:24/03/18
Measur.Unit:SI
TIME:16:57
Max.Load : 598.6 kN
Pace Rate : 10.0 KN/s
Stress : 26.60 MPa
HxWxD : 150x150x150

Sample 8

Type:Cube
DATE:24/03/18
Measur.Unit:SI
TIME:17:10
Max.Load : 520.5 kN
Pace Rate : 10.0 KN/s
Stress : 23.13 MPa
HxWxD : 150x150x150

Figure 4.37 Sample 7 & 8 compressive strength test result for C-25 concrete

<u>Sample 2 & 3 compressive strength test result for C-40 concrete (Size 15x15x15 cm)</u>

Sample 2

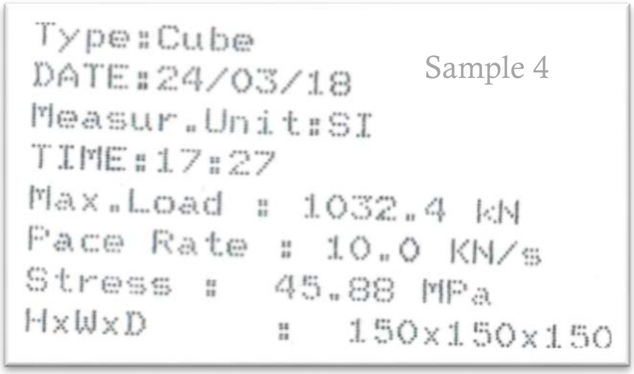
Type:Cube
DATE:24/03/18
Measur.Unit:SI
TIME:16:39
Max.Load : 1015.8 kN
Pace Rate : 10.0 KN/s
Stress : 45.14 MPa
HxWxD : 150x150x150

Sample 3

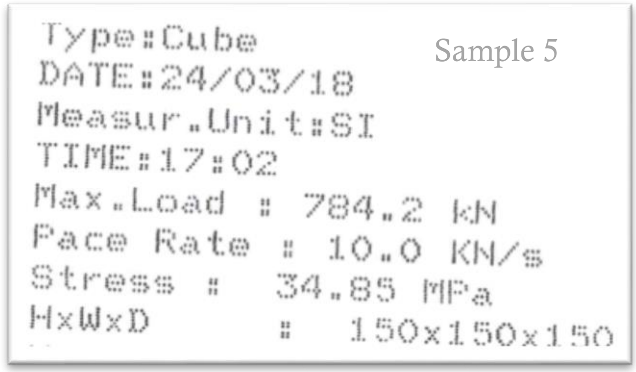
Type:Cube
DATE:24/03/18
Measur.Unit:Metric
TIME:16:02
Max.Load : 75990.0 kgf
Pace Rate : 680 kgf/s
Stress : 337.72 kgf/cm2
HxWxD : 150x150x150

Figure 4.38 Sample 2 & 3 compressive strength test result for C-40 concrete

Sample 4 & 5 compressive strength test result for C-40 concrete (Size 15x15x15 cm)


Type:Cube
DATE:24/03/18
Measur.Unit:SI
TIME:17:27
Max.Load : 1032.4 kN
Pace Rate : 10.0 KN/s
Stress : 45.88 MPa
HxWxD : 150x150x150

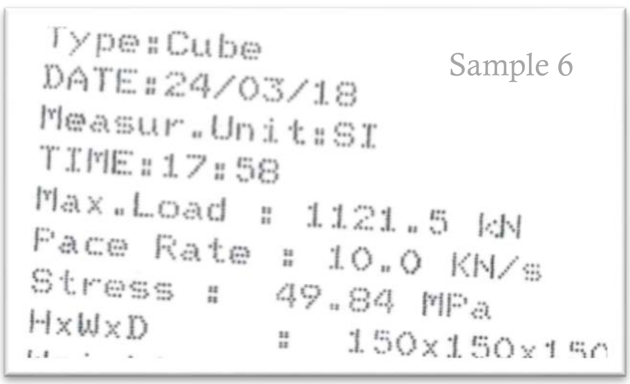
Sample 4


Type:Cube
DATE:24/03/18
Measur.Unit:SI
TIME:17:02
Max.Load : 784.2 kN
Pace Rate : 10.0 KN/s
Stress : 34.85 MPa
HxWxD : 150x150x150

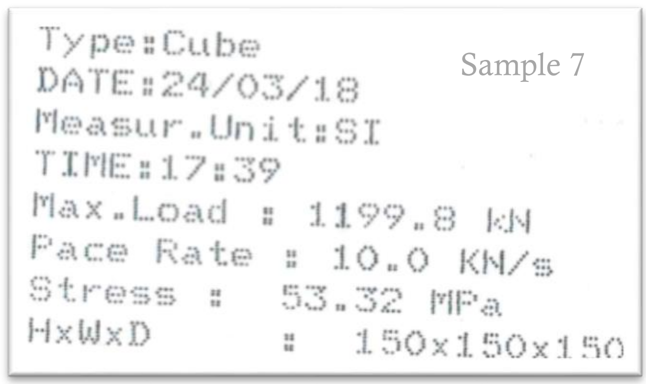
Sample 5

Figure 4.39 Sample 4 & 5 compressive strength test result for C-40 concrete

Sample 6 & 7 compressive strength test result for C-40 concrete (Size 15x15x15 cm)


Type:Cube
DATE:24/03/18
Measur.Unit:SI
TIME:17:58
Max.Load : 1121.5 kN
Pace Rate : 10.0 KN/s
Stress : 49.84 MPa
HxWxD : 150x150x150

Sample 6


Type:Cube
DATE:24/03/18
Measur.Unit:SI
TIME:17:39
Max.Load : 1199.8 kN
Pace Rate : 10.0 KN/s
Stress : 53.32 MPa
HxWxD : 150x150x150

Sample 7

Figure 4.40 Sample 6 & 7 compressive strength test result for C-40 concrete

Sample 8 compressive strength test result for C-40 concrete (Size 15x15x15 cm)

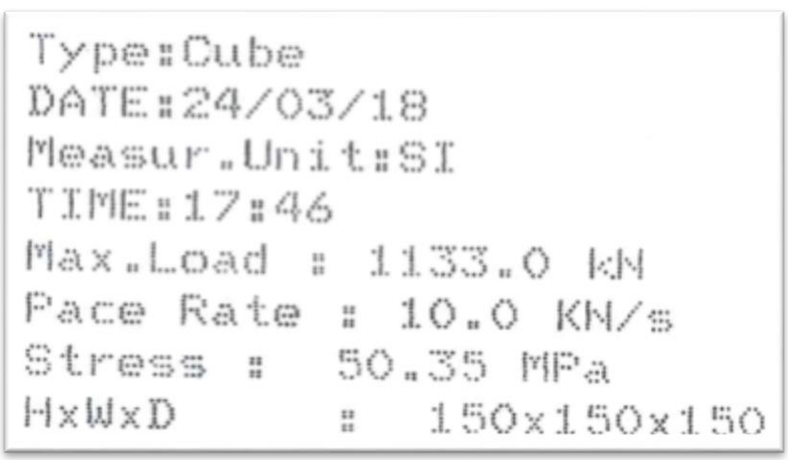

Type:Cube
DATE:24/03/18
Measur.Unit:SI
TIME:17:46
Max.Load : 1133.0 kN
Pace Rate : 10.0 KN/s
Stress : 50.35 MPa
HxWxD : 150x150x150

Figure 4.41 Sample 8 compressive strength test result for C-40 concrete

Moreover, the test results given above in graphical form, compressive strength test results at the age of seven days summarized as shown in the table given below.

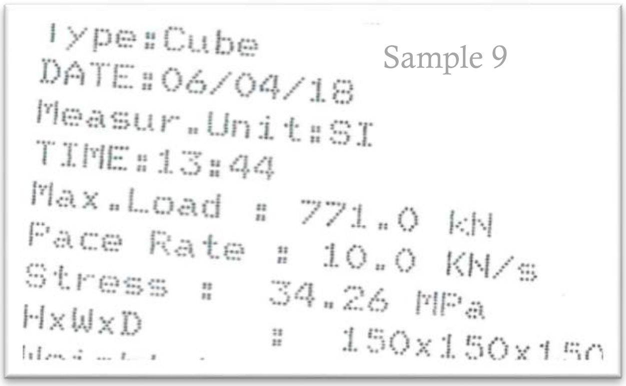
Table 4.4 Seven days compressive strength test result

Sample No	**Date of casted**	**Date of tasted**	**Dimension (mm)**	**Max Load (KN)**	**Compressive strength (mpa)**	**Concrete Grade**
360 kg of cement, 600.8 kg of Sand, 1154.2 kg of aggregate & 200 liter of water for 1m3 concrete work						
1	7-Mar-18	24-Mar-18	150x150x150	561.60	24.96	C-25
2			150x150x150	520.50	23.13	
3			150x150x150	545.00	24.22	
8			150x150x150	520.50	23.13	
				Average	**23.86**	
450 kg of cement, 643.16 kg of Sand, 1146.4 kg of aggregate & 195 liter of water for 1m3 concrete						
4	9-Mar-18	24-Mar-18	150x150x150	561.60	24.96	C-25
5			150x150x150	561.60	24.96	
6			150x150x150	545.00	24.22	
7			150x150x150	598.60	26.60	
				Average	**25.19**	
360 kg of cement, 600.8 kg of Sand, 1154.2 kg of aggregate, 2% admixture by weight of cement & w/c = 0.3 for 1m^3 concrete						
1	8-Mar-18	24-Mar-18	150x150x150	784.20	34.85	C-40
2			150x150x150	1015.80	45.14	
3			150x150x150	759.90	33.77	
5			150x150x150	784.20	34.85	
				Average	**37.153**	
450 kg of cement, 643.16 kg of Sand, 1146.4 kg of aggregate, 1.5% admixture by weight of cement & w/c = 0.3 for 1m^3 concrete						
4	10-Mar-18	24-Mar-18	150x150x150	1032.40	45.88	C-40
6			150x150x150	1121.50	49.84	
7			150x150x150	1199.80	53.32	
8			150x150x150	1133.00	50.35	
				Average	**49.848**	

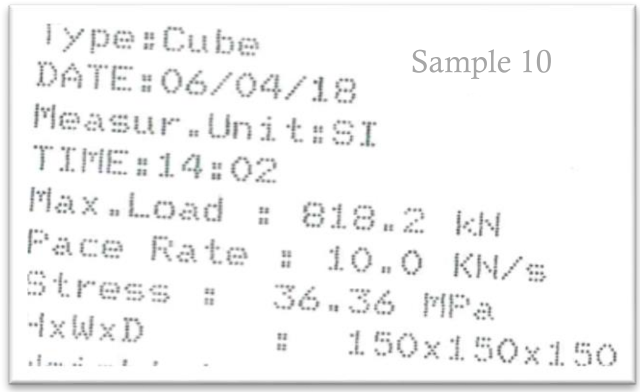
Remark 4.11 The results of compressive strength test for lost samples ((i.e sample no 1, 2 & 3 for C-25 concrete, sample no 1 for C-40) due to improper functioning of F 060 Universal Testing Machine are taken as the same value as similar tests values.

4.3.2 TWENTY EIGHT DAYS COMPRESSIVE STRENGTH TEST RESULT

Sample 9 & 10 compressive strength test result for C-25 concrete (Size 15x15x15 cm)


Type:Cube
DATE:06/04/18
Measur.Unit:SI
TIME:13:44
Max.Load : 771.0 kN
Pace Rate : 10.0 KN/s
Stress : 34.26 MPa
HxWxD : 150x150x150

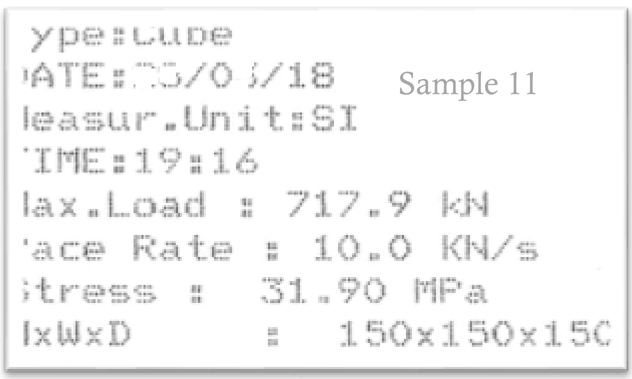
Sample 9


Type:Cube
DATE:06/04/18
Measur.Unit:SI
TIME:14:02
Max.Load : 818.2 kN
Pace Rate : 10.0 KN/s
Stress : 36.36 MPa
HxWxD : 150x150x150

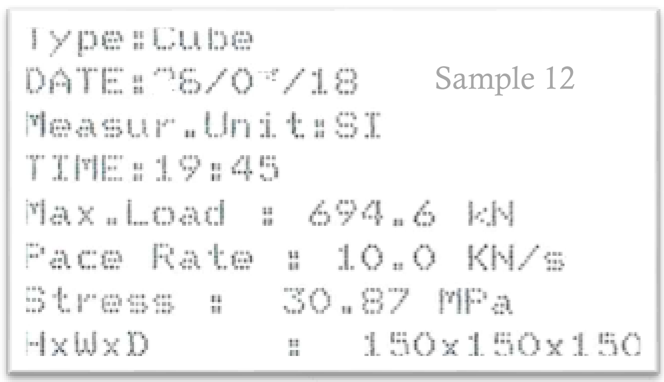
Sample 10

Figure 4.42 Sample 9 & 10 compressive strength test result for C-25 concrete

Sample 11 & 12 compressive strength test result for C-25 concrete (Size 15x15x15 cm)


ype:Cube
ATE:[illegible]/0[illegible]/18
leasur.Unit:SI
IME:19:16
lax.Load : 717.9 kN
ace Rate : 10.0 KN/s
tress : 31.90 MPa
IxWxD : 150x150x150

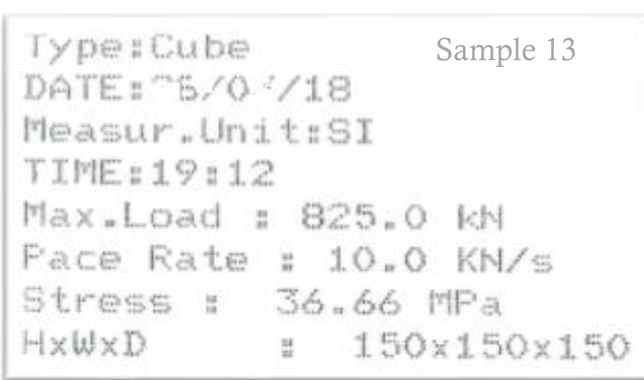
Sample 11


Type:Cube
DATE:[illegible]6/0[illegible]/18
Measur.Unit:SI
TIME:19:45
Max.Load : 694.6 kN
Pace Rate : 10.0 KN/s
Stress : 30.87 MPa
HxWxD : 150x150x150

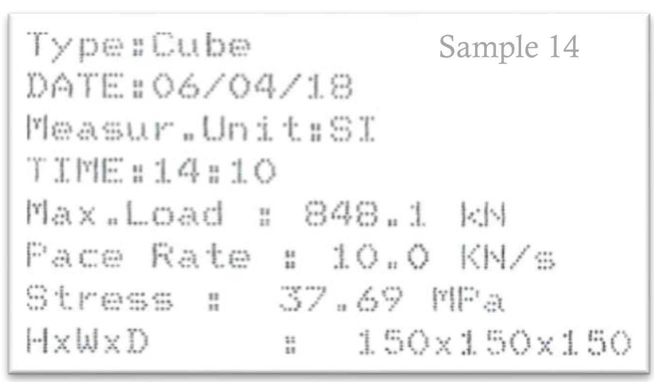
Sample 12

Figure 4.43 Sample 7 & 8 compressive strength test result for C-25 concrete

Sample 13 & 14 compressive strength test result for C-25 concrete (Size 15x15x15 cm)


Type:Cube
DATE:[illegible]6/0[illegible]/18
Measur.Unit:SI
TIME:19:12
Max.Load : 825.0 kN
Pace Rate : 10.0 KN/s
Stress : 36.66 MPa
HxWxD : 150x150x150

Sample 13


Type:Cube
DATE:06/04/18
Measur.Unit:SI
TIME:14:10
Max.Load : 848.1 kN
Pace Rate : 10.0 KN/s
Stress : 37.69 MPa
HxWxD : 150x150x150

Sample 14

Figure 4.44 Sample 13 & 14 compressive strength test result for C-25 concrete

Sample 15 & 16 compressive strength test result for C-40 concrete (Size 15x15x15 cm)

Sample 15

Type:Cube
DATE:06/04/18
Measur.Unit:SI
TIME:14:38
Max.Load : 865.3 kN
Pace Rate : 10.0 KN/s
Stress : 38.45 MPa
HxWxD : 150x150x150

Sample 16

Type:Cube
DATE:06/04/18
Measur.Unit:SI
TIME:13:54
Max.Load : 882.1 kN
Pace Rate : 10.0 KN/s
Stress : 39.20 MPa
HxWxD : 150x150x150

Figure 4.45 Sample 15 & 16 compressive strength test result for C-25 concrete

Sample 9 & 10 compressive strength test result for C-40 concrete (Size 15x15x15 cm)

Sample 9

Type:Cube
DATE:06/04/18
Measur.Unit:SI
TIME:13:31
Max.Load : 975.9 kN
Pace Rate : 10.0 KN/s
Stress : 43.37 MPa
HxWxD : 150x150x150

Sample 10

Type:Cube
DATE:06/04/18
Measur.Unit:SI
TIME:14:25
Max.Load : 1039.6 kN
Pace Rate : 10.0 KN/s
Stress : 46.20 MPa
HxWxD : 150x150x150

Figure 4.46 Sample 9 & 10 compressive strength test result for C-40 concrete

Sample 11 & 12 compressive strength test result for C-40 concrete (Size 15x15x15 cm)

Sample 11

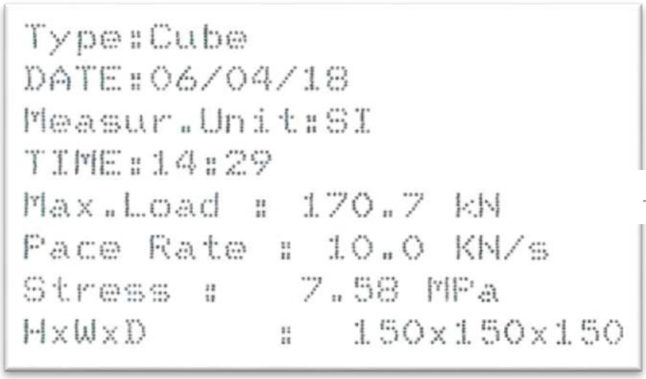
Type:Cube
DATE:[illegible]6/0[illegible]/18
Measur.Unit:SI
TIME:19:03
Max.Load : 1056.6 kN
Pace Rate : 10.0 KN/s
Stress : 46.96 MPa
HxWxD : 150x150x150

Sample 12

Type:Cube
DATE:[illegible]6/0[illegible]/18
Measur.Unit:SI
TIME:19:24
Max.Load : 963.6 kN
Pace Rate : 10.0 KN/s
Stress : 42.82 MPa
HxWxD : 150x150x150

Figure 4.47 Sample 11 & 12 compressive strength test result for C-40 concrete

<u>Sample 13 compressive strength test result for C-40 concrete (Size 15x15x15 cm)</u>


Type:Cube
DATE:06/04/18
Measur.Unit:SI
TIME:14:29
Max.Load : 170.7 kN
Pace Rate : 10.0 KN/s
Stress : 7.58 MPa
HxWxD : 150x150x150

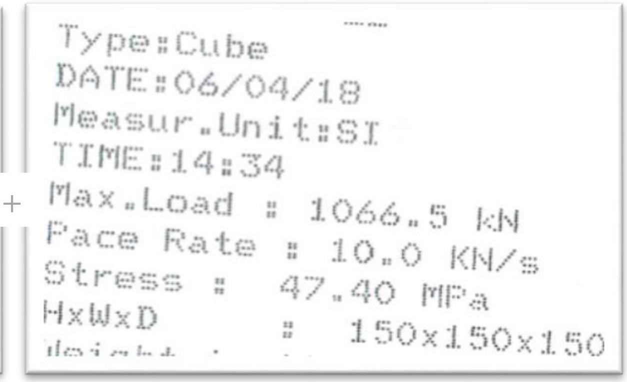
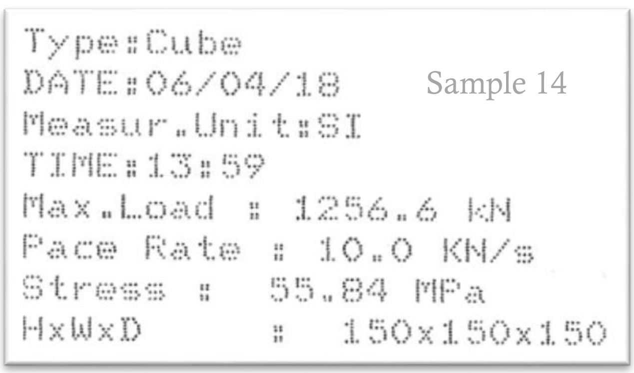

Type:Cube
DATE:06/04/18
Measur.Unit:SI
TIME:14:34
Max.Load : 1066.5 kN
Pace Rate : 10.0 KN/s
Stress : 47.40 MPa
HxWxD : 150x150x150

Figure 4.48 Sample 13 compressive strength test result for C-40 concrete

<u>Remark 4.12</u> - The test for sample 13 has been stopped after the sample stressed 7.58mpa due unloading of machine by mistake and the sample retest again and 47.40mpa was obtained

<u>Sample 14 & 15 compressive strength test result for C-40 concrete (Size 15x15x15 cm)</u>


Type:Cube
DATE:06/04/18
Sample 14
Measur.Unit:SI
TIME:13:59
Max.Load : 1256.6 kN
Pace Rate : 10.0 KN/s
Stress : 55.84 MPa
HxWxD : 150x150x150

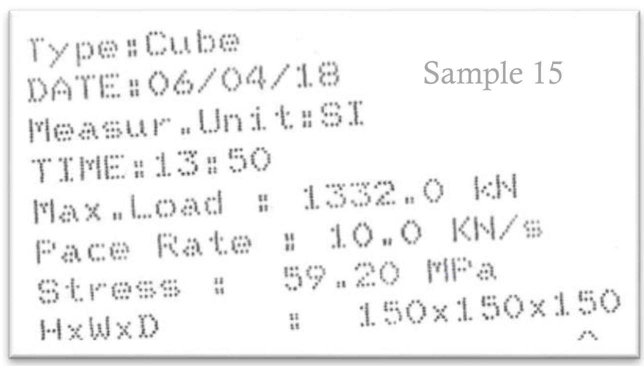

Type:Cube
DATE:06/04/18
Sample 15
Measur.Unit:SI
TIME:13:50
Max.Load : 1332.0 kN
Pace Rate : 10.0 KN/s
Stress : 59.20 MPa
HxWxD : 150x150x150

Figure 4.49 Sample 14 & 15 compressive strength test result for C-40 concrete

<u>Sample 16 compressive strength test result for C-40 concrete (Size 15x15x15 cm)</u>

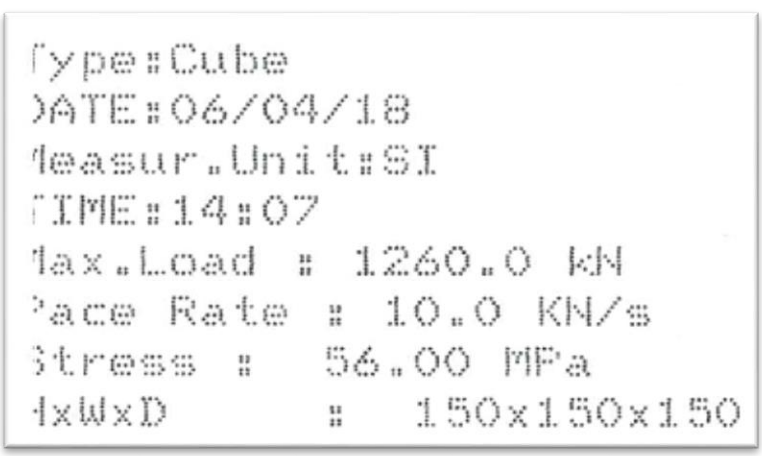

ype:Cube
ATE:06/04/18
easur.Unit:SI
IME:14:07
ax.Load : 1260.0 kN
ace Rate : 10.0 KN/s
tress : 56.00 MPa
xWxD : 150x150x150

Figure 4.50 Sample 16 compressive strength test result for C-40 concrete

Moreover, the test results given above in graphical form, compressive strength test results at the age of twenty days summarized as shown in the table given below.

Table 4.5 Twenty days compressive strength test result

Sample No	**Date of casted**	**Date of tasted**	**Dimension (mm)**	**Max Load (KN)**	**Compressive strength (mpa)**	**Concrete Grade**
360 kg of cement, 600.8 kg of Sand, 1154.2 kg of aggregate & 200 liter of water for 1m^3 concrete work						
9	7-Mar-18	6-Apr-18	150x150x150	771	34.26	C-25
10			150x150x150	818.2	36.36	
11			150x150x150	717.9	31.90	
12			150x150x150	694.6	30.87	
Average					**33.35**	
450 kg of cement, 643.16 kg of Sand, 1146.4 kg of aggregate & 195 liter of water for 1m^3 concrete						
13	9-Mar-18	6-Apr-18	150x150x150	825	36.66	C-25
14			150x150x150	848.1	37.69	
15			150x150x150	865.3	38.45	
16			150x150x150	882.1	39.20	
Average					**38.00**	
360 kg of cement, 600.8 kg of Sand, 1154.2 kg of aggregate, 2% admixture by weight of cement & w/c = 0.3 for 1m^3 concrete						
9	8-Mar-18	6-Apr-18	150x150x150	975.9	43.37	C-40
10			150x150x150	1039.5	46.2	
11			150x150x150	1056.6	46.96	
12			150x150x150	963.6	42.82	
Average					**44.84**	
450 kg of cement, 643.16 kg of Sand, 1146.4 kg of aggregate, 1.5% admixture by weight of cement & w/c = 0.3 for 1m^3 concrete						
13	10-Mar-18	6-Apr-18	150x150x150	1237.2	54.98	C-40
14			150x150x150	1256.6	55.84	
15			150x150x150	1332	59.20	
16			150x150x150	1260	56.00	
Average					**56.505**	

5. INTERPRETATION OF TEST AND DESIGN RESULT

5.1 INTERPRETATION OF TEST RESULT

The laboratory test is conducted to investigate the effect of concrete grade enhancer admixture on structural design of reinforced concrete structure in related to concrete performance. The compressive strength test is conducted to know the mix design for C-25 concrete (concrete without concrete grade enhancer admixture) and for C-40 concrete (concrete with concrete grade enhancer admixture). Whereas the flexural strength test is conducted to know the flexural strength and ductility behavior of concrete. Moreover, the laboratory test for compressive strength test is done to determine the tensile strength of concrete. The tensile strength of concrete is determine from compressive strength of concrete using the empirical formula.

Generally the laboratory test uses to determine the amount of admixture added on C-25 concrete mix to get C-40 concrete and to know performance of concrete mix.

5.1.1 INTERPRETATION OF COMPRESSIVE STRENGTH TEST RESULT

Compressive strength test is conducted for 32 cube concrete samples to know the amount of cement, sand, aggregate, water and admixture to get C-25 & C-40 concrete at the age of 7 and 28 days. According to ACI mix design table 8.27 the requirement of average compressive strength of concrete at the age of 28 days for good, fair and poor working condition is 120%, 135% and 150% of the laboratory test result respectively.

The expected compressive strength of concrete at different days is given in following table shown below using the ACI mix design code.

Table 5.1 Expected concrete compressive strength at various ages

Age (Day)	Expected strength (%)	Expected strength (Mpa)					
		C-25 Concrete			C-40 Concrete		
		Working Condition			Working Condition		
		Good	Fair	Poor	Good	Fair	Poor
1	16	4.8	5.4	6	7.68	8.64	9.6
3	40	12	13.5	15	19.2	21.6	24
7	65	19.5	21.94	24.4	31.2	35.1	39
14	90	27	30.38	33.8	43.2	48.6	54
28	99	29.7	33.41	37.125	47.52	53.46	59.4

As clearly shown on table 5.1 average compressive strength of concrete ranges between 29.70mpa to 37.13mpa for C-25 concrete and 47.52mpa to 59.40mpa for C-40 concrete at the age of 28 days depending on working condition as per ACI mix design manual. Have such expected value of average compressive strength let as interpret the compressive strength test result using the table given below.

Table 5.2 Interpretation of compressive strength test result

Sam. No	Age of Concrete (Day)	Trial Mix Type	Test Result (Mpa)	Percentage of strength			Grade	Status		
				Working Condition				Working Condition		
				Good	Fair	Poor		Good	Fair	Poor
1	7	I	24.96	83.20%	73.96%	66.56%	C-25	OK!	OK!	OK!
2			23.13	77.10%	68.53%	61.68%		OK!	OK!	Not ok!
3			24.22	80.73%	71.76%	64.59%		OK!	OK!	Not ok!
8			23.13	77.10%	68.53%	61.68%		OK!	OK!	Not ok!
Average			**23.86**	**79.53%**	**70.70%**	**63.63%**		**OK!**	**OK!**	**Not ok!**
4	7	II	24.96	83.20%	73.96%	66.56%	C-25	OK!	OK!	OK!
5			24.96	83.20%	73.96%	66.56%		OK!	OK!	OK!
6			24.22	80.73%	71.76%	64.59%		OK!	OK!	Not ok!
7			26.6	88.67%	78.81%	70.93%		OK!	OK!	OK!
Average			**25.19**	**83.95%**	**74.62%**	**67.16%**		**OK!**	**OK!**	**OK!**
1	7	III	34.85	72.60%	64.54%	58.08%	C-40	OK!	Not ok!	Not ok!
2			45.14	94.04%	83.59%	75.23%		OK!	OK!	OK!
3			33.77	70.35%	62.54%	56.28%		OK!	Not ok!	Not ok!
5			34.85	72.60%	64.54%	58.08%		OK!	Not ok!	Not ok!
Average			**37.15**	**77.40%**	**68.80%**	**61.92%**		**OK!**	**OK!**	**Not ok!**
4	7	IV	45.88	95.58%	84.96%	76.47%	C-40	OK!	OK!	OK!
6			49.84	103.83%	92.30%	83.07%		OK!	OK!	OK!
7			53.32	111.08%	98.74%	88.87%		OK!	OK!	OK!
8			50.35	104.90%	93.24%	83.92%		OK!	OK!	OK!
Average			**49.85**	**103.85%**	**92.31%**	**83.08%**		**OK!**	**OK!**	**OK!**
9	28	I	34.26	114.20%	101.51%	91.36%	C-25	OK!	OK!	Not ok!
10			36.36	121.20%	107.73%	96.96%		OK!	OK!	Not ok!
11			31.90	106.33%	94.52%	85.07%		OK!	Not ok!	Not ok!
12			30.87	102.90%	91.47%	82.32%		OK!	Not ok!	Not ok!
Average			**33.35**	**111.16%**	**98.81%**	**88.93%**		**OK!**	**Not ok!**	**Not ok!**
13	28	II	36.66	122.20%	108.62%	97.76%	C-25	OK!	OK!	Not ok!
14			37.69	125.63%	111.67%	100.51%		OK!	OK!	OK!
15			38.45	128.17%	113.93%	102.53%		OK!	OK!	OK!
16			39.20	130.67%	116.15%	104.53%		OK!	OK!	OK!
Average			**38.00**	**126.67%**	**112.59%**	**101.33%**		**OK!**	**OK!**	**OK!**
9	28	III	43.37	90.35%	80.31%	72.28%	C-40	Not ok!	Not ok!	Not ok!
10			46.2	96.25%	85.56%	77.00%		Not ok!	Not ok!	Not ok!
11			46.96	97.83%	86.96%	78.27%		Not ok!	Not ok!	Not ok!
12			42.82	89.21%	79.30%	71.37%		Not ok!	Not ok!	Not ok!
Average			**44.84**	**93.41%**	**83.03%**	**74.73%**		**Not ok!**	**Not ok!**	**Not ok!**
13	28	IV	54.98	114.54%	101.81%	91.63%	C-40	OK!	OK!	Not ok!
14			55.84	116.33%	103.41%	93.07%		OK!	OK!	Not ok!
15			59.20	123.33%	109.63%	98.67%		OK!	OK!	Not ok!
16			56.00	116.67%	103.70%	93.33%		OK!	OK!	Not ok!
Average			**56.505**	**117.72%**	**104.64%**	**94.18%**		**OK!**	**OK!**	**Not ok!**

Considering fair working condition the required average compressive strength of concrete at the age of 28 days computed as follow;

- For C-25 concrete: 1.35*25mpa = **33.75 Mpa**
- For C-40 concrete: 1.35*40mpa = **54.00 Mpa**

As clearly shown on table 5.2 the trial mix type satisfied the requirement of average compressive strength at the age of 28 days is trial mix type II & IV for C-25 & C-40 concrete respectively using ACI mix design code.

Moreover, there are also other codes for concrete mix design such as India Standard and Euro codes in addition to the ACI mix design code. Accordingly, let as also interpret the compressive strength test result as per the Indian Standard, IS 10262-2009 as follow.

The target concrete compressive strength denoted by f_t obtained by compressive strength of concrete at the age of 28 days (f_{ck}) and value of standard deviation (S) is computed using the formula given below.

$f_t = f_{ck} + 1.65S$……………………………………………………………………….Equation 5.1

The standard deviation for different concrete grade obtained from the table 5.3 shown below.

Table 5.3 Target concrete compressive strength and standard deviation

Grade of Concrete	Standard Deviation S (Mpa)	Target Strength f_t (Mpa)	Grade of Concrete	Standard Deviation S (Mpa)	Target Strength f_t (Mpa)
M10	3.5	15.775	M35	5	43.25
M15	3.5	20.775	**M40**	**5**	**48.25**
M20	4	26.6	M45	5	53.25
M25	**4**	**31.6**	M50	5	58.25
M30	5	38.25			

As clearly shown on table 5.3 the expected or target concrete compressive strength as per the Indian mix design standard is 31.6 Mpa and 48.25 Mpa for C-25 and C-40 concrete respectively. Accordingly, trial mix type I and III satisfied the requirement as per Indian Standard, IS 10262-2009.

Generally, the average compressive strength at the age of twenty eight days for all trial mix as per the ACI and IS mix design codes interpreted as follow in the table given below.

Table 5.4 Comparison of compressive strength test results for ACI & IS mix design code

Trial Mix Type		I	II	III	IV
Test Result at the age of 7 days (Mpa)		23.86	25.19	37.15	49.85
Test Result at the age of 28 days (Mpa)		33.35	38	44.84	56.505
Grade of Concrete		C-25	C-25	C-40	C-40
% Strength at 7 days	ACI Mix Design	70.696	74.637	68.79	92.31
	IS Mix Design	75.51	79.715	76.99	103.31
Target Strength (Mpa)	ACI Mix Design	33.75		54	
	IS Mix Design	31.6		48.25	
Remark	ACI Mix Design	Not Satisfied	Satisfied	Not Satisfied	Satisfied
	IS Mix Design	Satisfied	Satisfied but exaggerated	Satisfied	Satisfied but exaggerated

As clearly shown above tables 5.2 and 5.3 the required target compressive strength differ from code to code. The choice of different mix design codes depend on working conditions and applicability. The most commonly used code for mix design in our country is the ACI mix design code; however the ACI mix design is somewhat expensive for poor countries like Ethiopia. Moreover, the characteristics, economical status, social, environmental and construction working conditions in America is quite different from Ethiopia, since Ethiopian is a developing country and located in tropical regions. Considering such facts, the Indian Standard mix design code is more preferable for our country.

Thus, using the Indian Standard mix design code, IS 10262-2009 the optimal trial mix that satisfied the requirement for target strength of C-25 and C-40 concrete is trial mix type I (concrete mix without admixture) and III (concrete mix with concrete grade enhancer admixture) respectively

Accordingly, the amount of concrete grade enhancer admixture that gives C-40 concrete using the same mixing proportion cement, sand and aggregate of C-25 is 2% by weight of cement with water cement ratio of 0.3.

5.1.2 INTERPRETATION OF FLEXURAL STRENGTH TEST RESULT

Flexural strength test is conducted to determine flexural strength of concrete; it helps to know the performance of a certain concrete mix in related to bending resistance of a concrete beam. Moreover, the performance of concrete also measured based on compressive and tensile strength or concrete ductility. The compressive strength is measured using cubic compression test and flexural strength is determined from flexural strength test. Whereas for this research tensile strength of concrete is determined from compressive strength test result using empirical formula.

The expected flexural strength of concrete can be determine using the formula described in IS 516.

- Flexural strength, $f_{cr} = 0.7\ f_{ck}^{1/2}$ $f_{ck} = 0.8f_{cu}$
- Tensile strength, $f_{ct} = 0.21f_{ck}^{2/3}$ f_{ck} is the characteristic cylindrical strength of concrete in mpa

Thus, the expected flexural and tensile strength for C-25 and C-40 concrete is computed as follow;

- For C-25 concrete:
  - $f_{cr} = 0.7*(0.8*25)^{1/2} = 3.13$ Mpa,
  - Using AIC mix design method for fair working condition, $f_{cr} = 1.35*\ 3.13 =$ **4.23 Mpa**
  - $f_{ct} = 0.21*(0.8*25)^{2/3} =$ **1.547 Mpa**
- For C-40 concrete:
  - $f_{cr} = 0.7*(0.8*40)^{1/2} = 3.96$ Mpa,
  - Using AIC mix design method for fair working condition, $f_{cr} = 1.35*\ 3.96 =$ **5.35 Mpa**
  - $f_{ct} = 0.21*(0.8*40)^{2/3} =$ **2.117 Mpa**

Have such expected value of flexural strength let as interpret the flexural strength test result using the table given below.

Table 5.5 Interpretation of flexural strength test result

Sam. No	Age of Concrete (Day)	Trial Mix Type	Test Result (Mpa)	Percentage of strength Working Condition			Concrete Type	Status Working Condition		
				Good	Fair	Poor		Good	Fair	Poor
1	7	I	5.28	140.58%	124.96%	112.46%	C-25	OK!	OK!	OK!
2			4.86	129.39%	115.02%	103.51%		OK!	OK!	OK!
3			4.016	106.92%	95.04%	85.54%		OK!	OK!	OK!
8			3.776	100.53%	89.36%	80.43%		OK!	OK!	OK!
Average			**4.483**	**119.36%**	**106.09%**	**95.48%**		**OK!**	**OK!**	**OK!**
4	7	II	4.695	125.00%	111.11%	100.00%	C-25	OK!	OK!	OK!
5			4.695	125.00%	111.11%	100.00%		OK!	OK!	OK!
6			5.893	156.90%	139.46%	125.52%		OK!	OK!	OK!
7			3.776	100.53%	89.36%	80.43%		OK!	OK!	OK!
Average			**4.765**	**126.86%**	**112.76%**	**101.49%**		**OK!**	**OK!**	**OK!**
1	7	III	5.79	121.84%	108.31%	97.47%	C-40	OK!	OK!	OK!
2			6.42	135.10%	120.09%	108.08%		OK!	OK!	OK!
3			6.912	145.45%	129.29%	116.36%		OK!	OK!	OK!
5			5.087	107.05%	95.16%	85.64%		OK!	OK!	OK!
Average			**6.052**	**127.36%**	**113.21%**	**101.89%**		**OK!**	**OK!**	**OK!**
4	7	IV	7.98	167.93%	149.27%	134.34%	C-40	OK!	OK!	OK!
6			7.98	167.93%	149.27%	134.34%		OK!	OK!	OK!
7			6.256	131.65%	117.02%	105.32%		OK!	OK!	OK!
8			6.16	129.63%	115.23%	103.70%		OK!	OK!	OK!

Sam. No	Age of Concrete (Day)	Trial Mix Type	Test Result (Mpa)	Percentage of strength			Concrete Type	Status		
				Working Condition				Working Condition		
				Good	Fair	Poor		Good	Fair	Poor
Average			**7.094**	**149.28%**	**132.70%**	**119.43%**		**OK!**	**OK!**	**OK!**
9	28	I	4.333	115.36%	102.54%	92.29%	C-25	OK!	OK!	Not ok!
10			5.232	139.30%	123.82%	111.44%		OK!	OK!	OK!
11			5.085	135.38%	120.34%	108.31%		OK!	OK!	OK!
12			5.085	135.38%	120.34%	108.31%		OK!	OK!	OK!
Average			**4.934**	**131.36%**	**116.76%**	**105.09%**		OK!	**OK!**	OK!
13	28	II	4.520	120.34%	106.97%	96.27%	C-25	OK!	OK!	Not ok!
14			6.043	160.89%	143.01%	128.71%		OK!	OK!	OK!
15			6.735	179.31%	159.39%	143.45%		OK!	OK!	OK!
16			5.835	155.35%	138.09%	124.28%		OK!	OK!	OK!
Average			**5.783**	**153.97%**	**136.87%**	**123.18%**		**OK!**	**OK!**	**OK!**
9	28	III	5.920	124.58%	110.74%	99.66%	C-40	OK!	OK!	OK!
10			7.328	154.21%	137.07%	123.37%		OK!	OK!	OK!
11			7.470	157.20%	139.73%	125.76%		OK!	OK!	OK!
12			7.470	157.20%	139.73%	125.76%		OK!	OK!	OK!
Average			**7.047**	**148.30%**	**131.82%**	**118.64%**		**OK!**	**OK!**	**OK!**
13	28	IV	5.833	122.75%	109.11%	98.20%	C-40	OK!	OK!	Not ok!
14			7.643	160.84%	142.97%	128.67%		OK!	OK!	OK!
15			8.595	180.87%	160.77%	144.70%		OK!	OK!	OK!
16			7.920	166.67%	148.15%	133.33%		OK!	OK!	OK!
Average			**7.498**	**157.78%**	**140.25%**	**126.22%**		**OK!**	**OK!**	**OK!**

As clearly shown on table 5.5 all trial mix types satisfied the requirement of average flexural strength at the age of 7 as well as 28 days. Moreover, the concrete mixes with concrete grade enhancer admixture (trial mix type III & IV) have greater flexural strength than concrete mixes without concrete grade enhancer admixture (trial mix type I & II). This shows adding concrete grade enhancer admixture on concrete mix does not have adverse effect on concrete bending resistance or ductility.

5.1.3 INTERPRETATION OF CONCRETE PERFORMANCE

As clearly shown on section 4 and section 5.1 the two type of concretes, concrete with concrete grade enhancer admixture (C-40 concrete) and concrete without concrete grade enhancer admixture (C-25 concrete) have different concrete strength. The C-40 concrete has higher compressive, flexural and tensile strength. Moreover, the C-40 concrete is more workable or has higher slump with a water cement ratio less than C-25 concrete. This shows the concrete mix with concrete grade enhancer admixture gives better concrete performance than a concrete a mix without concrete grade enhancer admixture.

Generally the comparison of the two concrete type summary as follow in the table shown below.

Table 5.6 Comparison of C-25 and C-40 concretes

Description	Concrete Type	
	C-25	C-40
Selected mix design code	IS 10262-2009	IS 10262-2009
Specified cube compressive strength (Mpa)	25	40
Specified one point flexural strength (Mpa)	3.13	3.96
Target Mean compressive Strength (Mpa)	31.6	48.25
Target Mean flexural Strength (Mpa)	4.23	5.35
Type of cement used	Dangote, PPC	Dangote, PPC
Aggregate type	Blending Aggregate	Blending Aggregate
Sand type	River sand	River sand
Slump Required (Cm)	2 - 8	2 - 8
Maximum size of aggregate (mm)	30	30
Batching type	Batching by weight	Batching by weight
Trail Mix Type	I	III
Amount cement used (Kg/m^3)	360	360
Amount sand used (Kg/m3)	600.8	600.8
Amount aggregate used (Kg/m^3)	1154.2	1154.2
Amount water used (Lit/m^3)	200	108
Amount admixture used (kg/m^3)	-	7.2
Average slump from test (Cm)	3.76	5.22
Age of concrete (Day)	28	28
Average compressive strength from test (Mpa)	33.35	44.84
Average flexural strength from test (Mpa)	4.934	7.047
Average tensile strength from calculation(Mpa)	1.547	2.117
Cost of concrete work (Birr/m^3) - Average	2800	3300

Furthermore, the performance of the two type of concretes interpreted in terms of their ductility behavior using flexural strength test results as shown given below in tabular and graphical form.

Table 5.7 Points of Load-Deformation curve for Sample 2

Deformation [mm/1000]	Load [KN]	Deformation [mm/1000]	Load [KN]	Deformation [mm/1000]	Load [KN]	Deformation [mm/1000]	Load [KN]
C-25 Concrete							
0.000	0.000	256.980	3.341	516.200	5.905	820.110	1.350
4.469	0.095	270.390	3.477	518.440	5.782	846.930	1.227
13.408	0.232	281.560	3.627	525.140	5.632	873.740	1.091
17.877	0.368	290.500	3.777	527.370	5.509	911.730	0.995
26.816	0.505	299.440	3.955	536.310	5.400	947.490	0.914
29.050	0.627	312.850	4.118	538.550	5.250	974.300	0.845
40.223	0.723	326.260	4.268	547.490	5.086	1012.300	0.791
53.631	0.845	332.960	4.418	554.190	4.909	1048.000	0.750
73.743	0.941	344.130	4.609	563.130	4.718	1088.300	0.682

Deformation [mm/1000]	Load [KN]	Deformation [mm/1000]	Load [KN]	Deformation [mm/1000]	Load [KN]	Deformation [mm/1000]	Load [KN]
82.682	1.036	353.070	4.800	565.360	4.568	1126.300	0.641
96.089	1.159	362.010	4.936	572.070	4.418	1168.700	0.559
107.260	1.282	370.950	5.073	581.010	4.173	1206.700	0.545
122.910	1.377	379.890	5.236	594.410	3.968	1249.200	0.491
129.610	1.514	386.590	5.386	601.120	3.764	1293.900	0.477
147.490	1.636	397.770	5.496	618.990	3.505	1331.800	0.450
156.420	1.786	404.470	5.673	630.170	3.259	1372.100	0.423
165.360	1.896	411.170	5.809	650.280	3.014	1405.600	0.395
174.300	2.018	426.820	5.918	668.160	2.755	1439.100	0.368
183.240	2.168	431.280	6.055	674.860	2.509	1483.800	0.355
192.180	2.291	440.220	6.191	690.500	2.291	1519.600	0.341
201.120	2.468	453.630	6.273	708.380	2.073	1559.800	0.300
214.530	2.632	462.570	6.423	730.730	1.950	1604.500	0.232
221.230	2.768	473.740	6.327	744.130	1.827	1638.000	0.245
234.640	2.918	480.450	6.218	757.540	1.732	1682.700	0.218
243.580	3.055	491.620	6.123	773.180	1.596		
245.810	3.191	502.790	6.014	793.300	1.446		
C-40 Concrete							
0.000	0.000	531.880	4.782	777.600	7.684	1141.500	3.798
3.110	0.141	534.990	4.853	780.720	7.807	1166.400	3.587
18.663	0.316	544.320	4.818	790.050	7.930	1175.700	3.446
34.215	0.545	550.540	4.853	796.270	8.053	1194.400	3.253
40.435	0.703	556.770	4.976	805.600	8.176	1213.100	3.130
43.546	0.862	562.990	5.029	821.150	8.317	1231.700	2.954
65.319	0.985	572.320	5.152	827.370	8.422	1250.400	2.796
96.423	1.108	578.540	5.240	833.590	8.528	1272.200	2.655
130.640	1.266	587.870	5.345	849.140	8.440	1306.400	2.514
146.190	1.371	597.200	5.257	855.370	8.281	1337.500	2.356
180.400	1.459	597.200	5.328	861.590	8.123	1368.600	2.163
205.290	1.635	606.530	5.415	867.810	7.930	1393.500	2.022
223.950	1.776	609.640	5.503	877.140	7.754	1430.800	1.881
245.720	1.952	615.860	5.609	889.580	7.560	1461.900	1.793
264.390	2.110	622.080	5.697	898.910	7.367	1496.100	1.670
286.160	2.303	634.530	5.785	914.460	7.121	1524.100	1.635
307.930	2.497	643.860	5.908	926.910	6.892	1555.200	1.530
335.930	2.708	656.300	6.031	939.350	6.717	1592.500	1.442
354.590	2.866	662.520	6.154	954.900	6.488	1626.700	1.371
367.030	3.007	674.960	6.277	967.340	6.277	1664.100	1.284
382.580	3.182	678.070	6.382	986.000	6.084	1701.400	1.231
398.130	3.288	684.290	6.470	995.330	5.925	1763.600	1.143

Deformation [mm/1000]	Load [KN]	Deformation [mm/1000]	Load [KN]	Deformation [mm/1000]	Load [KN]	Deformation [mm/1000]	Load [KN]
404.350	3.429	690.510	6.541	1007.800	5.714	1735.600	1.160
426.130	3.534	696.730	6.629	1017.100	5.539	1810.300	1.055
435.460	3.675	706.070	6.717	1032.700	5.380	1844.500	1.002
447.900	3.833	715.400	6.787	1045.100	5.152	1894.200	0.949
463.450	3.991	715.400	6.857	1060.700	4.958	1940.900	0.879
469.670	4.097	718.510	6.945	1073.100	4.818	1984.400	0.826
482.120	4.220	727.840	7.086	1082.400	4.607	2024.900	0.826
497.670	4.325	743.390	7.174	1098.000	4.413	2056.000	0.756
513.220	4.466	762.050	7.332	1113.500	4.255	2102.600	0.703
525.660	4.607	765.160	7.437	1122.900	4.079	2146.200	0.686
528.770	4.695	774.490	7.596	1129.100	3.974	2183.500	0.651

Accordingly, based on the above points given on table 5.7, the Load-Deformation graph for sample 2 with C-25 and C-40 is drawn in the figure as shown below.

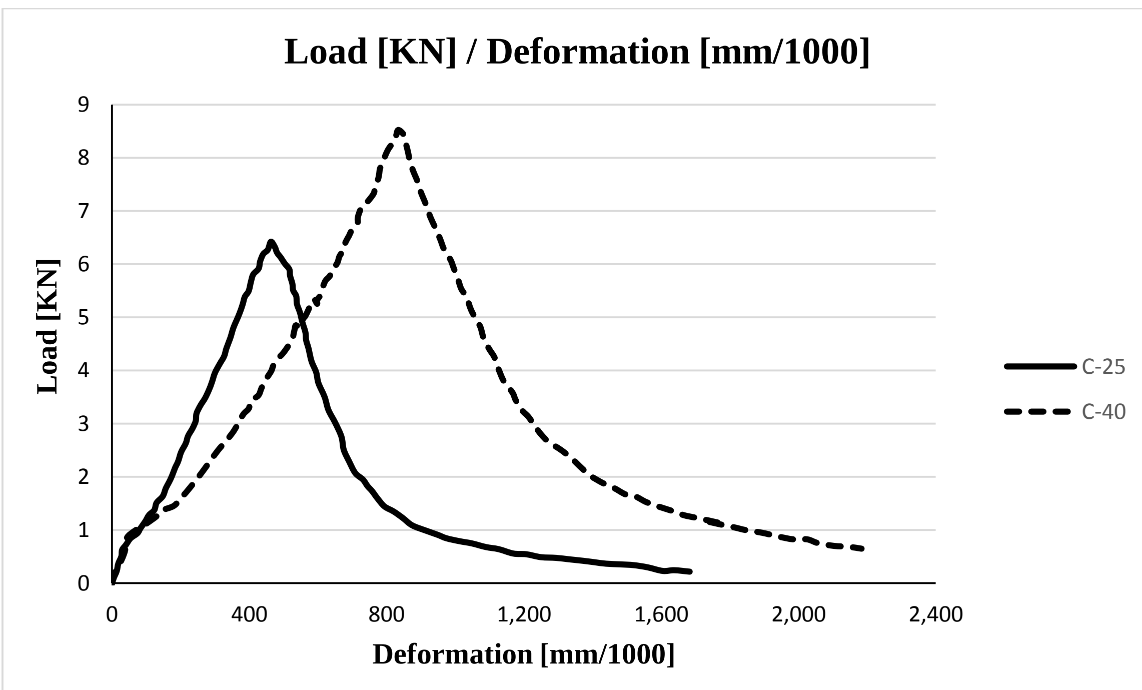


Figure 5.1 Load-Deformation Curve for Sample 2

Table 5.8 Points of Load-Deformation curve for Sample 3

Strain [1/1000]	**Stress [N/mm²]**	**Strain [1/1000]**	**Stress [N/mm²]**	**Strain [1/1000]**	**Stress [N/mm²]**	**Strain [1/1000]**	**Stress [N/mm²]**
C-25 Concrete							
0.000	0.000	0.354	2777.100	1.473	6072.600	3.006	1890.600
0.000	66.483	0.391	2926.800	1.600	5890.300	3.042	1724.500
0.000	149.590	0.409	3093.100	1.672	5707.800	3.132	1508.900
0.005	232.610	0.446	3209.600	1.726	5508.600	3.204	1293.100
0.009	348.960	0.483	3342.700	1.816	5342.700	3.295	1227.000
0.020	448.830	0.520	3492.500	1.870	5126.900	3.385	1077.800
0.038	581.880	0.538	3608.900	1.942	4961.000	3.494	945.260
0.020	681.520	0.611	3775.400	1.978	4811.500	3.621	862.690
0.020	748.010	0.612	3941.600	2.014	4645.500	3.730	829.900
0.039	847.810	0.631	4074.600	2.104	4413.200	3.893	730.860
0.039	930.910	0.704	4207.900	2.122	4280.300	4.020	681.520
0.021	1063.800	0.740	4341.000	2.176	4180.800	4.184	665.580
0.040	1147.000	0.777	4440.900	2.194	4031.300	4.366	616.480
0.058	1263.400	0.832	4590.700	2.266	3882.000	4.602	584.220
0.095	1396.500	0.869	4757.100	2.320	3682.800	4.802	551.810
0.095	1512.900	0.869	4890.000	2.411	3500.300	5.038	519.550
0.114	1612.700	0.924	5039.900	2.446	3234.500	5.202	520.230
0.151	1729.200	0.943	5172.900	2.555	3002.300	5.365	504.290
0.169	1878.800	1.016	5289.500	2.627	2836.400	5.511	488.270
0.170	2028.400	1.053	5522.400	2.663	2670.300	5.692	422.540
0.207	2144.900	1.108	5672.200	2.735	2521.100	5.910	406.830
0.243	2261.400	1.127	5855.100	2.753	2404.800	6.074	374.270
0.280	2411.100	1.200	5955.100	2.825	2288.700	6.274	375.100
0.317	2560.900	1.218	6088.200	2.879	2139.400	6.438	375.780
0.317	2660.600	1.310	6188.300	2.970	1990.200	6.583	376.380
C-40 Concrete							
0.000	0.000	3.476	5047.400	5.121	10379.000	9.705	2109.000
0.199	213.270	3.541	5308.100	5.321	10118.000	9.938	1872.000
0.364	426.540	3.640	5521.300	5.588	9810.400	10.238	1682.500
0.597	639.810	3.673	5782.000	5.788	9620.900	10.638	1564.000
0.695	900.470	3.738	5995.300	5.989	9455.000	11.004	1327.000
0.894	1113.700	3.838	6184.800	6.122	9218.000	11.604	1184.800
1.127	1208.500	3.837	6374.400	6.257	8838.900	11.970	1066.400
1.459	1255.900	3.903	6635.100	6.324	8507.100	12.270	947.870
1.658	1374.400	3.968	6824.600	6.425	8175.400	12.669	900.470

Strain [1/1000]	Stress [N/mm²]	Strain [1/1000]	Stress [N/mm²]	Strain [1/1000]	Stress [N/mm²]	Strain [1/1000]	Stress [N/mm²]
1.891	1564.000	4.001	7061.600	6.593	7796.200	13.035	829.380
2.056	1753.600	4.067	7227.500	6.727	7346.000	13.401	758.290
2.189	1990.500	4.099	7440.800	6.862	6895.700	13.800	710.900
2.321	2227.500	4.132	7748.800	6.996	6516.600	14.166	639.810
2.453	2535.500	4.230	8080.600	7.164	6161.100	14.666	568.720
2.552	2748.800	4.296	8317.500	7.298	5734.600	15.131	545.020
2.651	2962.100	4.362	8578.200	7.499	5331.800	15.730	521.330
2.750	3175.400	4.428	8791.500	7.700	4976.300	15.963	497.630
2.849	3412.300	4.460	9004.700	7.901	4597.200	16.329	473.930
2.948	3601.900	4.492	9289.100	8.135	4218.000	16.728	426.540
3.047	3767.800	4.558	9573.500	8.302	3910.000	17.127	450.240
3.146	4028.400	4.624	9810.400	8.503	3530.800	17.460	379.150
3.245	4265.400	4.656	10024.000	8.737	3128.000	18.092	379.150
3.278	4431.300	4.722	10213.000	8.937	2819.900	18.591	379.150
3.344	4668.200	4.755	10450.000	9.104	2630.300	19.090	379.150
3.443	4881.500	4.887	10569.000	9.405	2369.700	19.555	379.150

Accordingly, based on the above points given on table 5.8, the Load-Deformation graph for sample 2 with C-25 and C-40 is drawn in the figure as shown below.

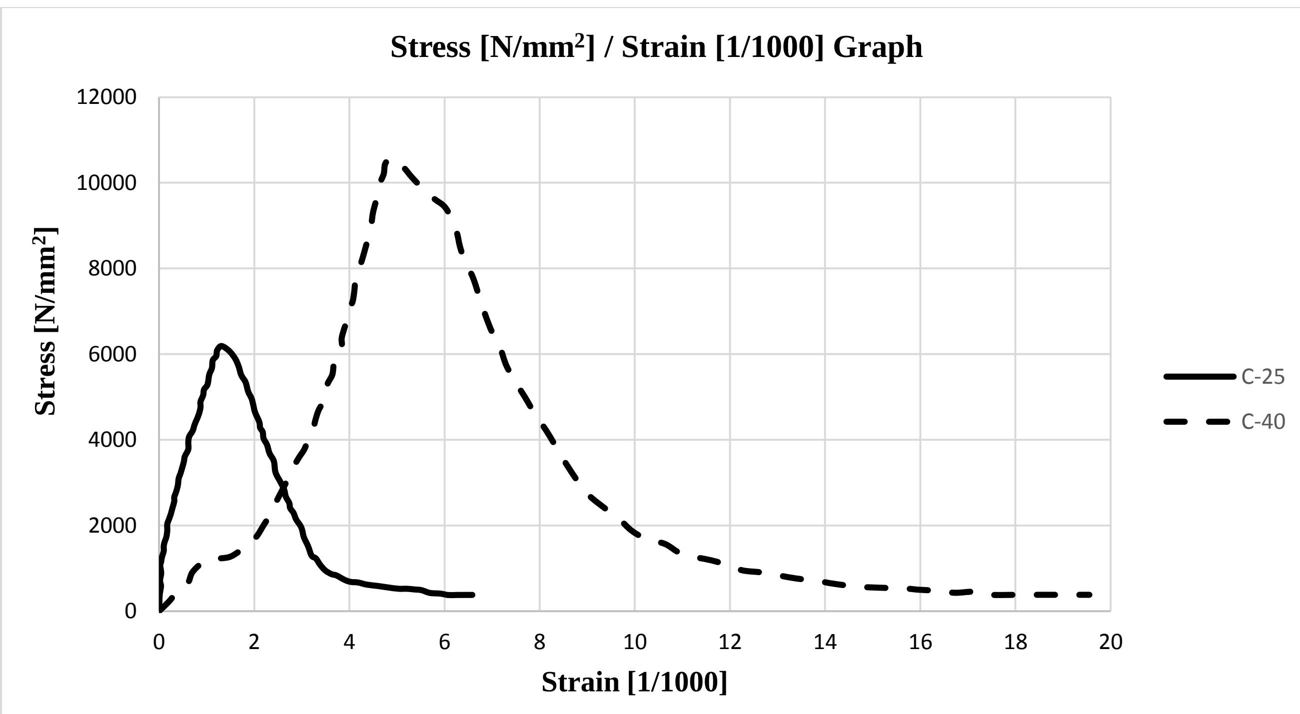


Figure 5.2 Stress-Strain Curve for Sample 3

Table 5.9 Points of Stress-Strain curve for Sample 5

Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]
C-25 Concrete							
0.000	0.000	1.136	9385.700	2.161	13780.000	6.278	7094.200
0.032	251.120	1.183	9856.500	2.334	13372.000	6.467	6937.200
0.095	627.800	1.246	10327.000	2.492	12996.000	6.672	6748.900
0.142	973.090	1.262	10578.000	2.603	12682.000	6.893	6623.300
0.189	1287.000	1.293	10924.000	2.697	12430.000	7.082	6403.600
0.237	1600.900	1.325	11238.000	2.808	12117.000	7.256	6215.200
0.284	1977.600	1.357	11520.000	2.902	11834.000	7.413	6152.500
0.347	2417.000	1.372	11865.000	3.013	11552.000	7.634	6089.700
0.379	2699.600	1.420	12117.000	3.123	11238.000	7.839	6058.300
0.394	3044.800	1.435	12462.000	3.218	10892.000	8.060	6026.900
0.410	3327.400	1.483	12682.000	3.360	10484.000	8.281	5995.500
0.489	3547.100	1.498	12964.000	3.533	10139.000	8.470	5964.100
0.521	3986.500	1.546	13215.000	3.722	9730.900	8.659	5932.700
0.568	4426.000	1.546	13466.000	3.849	9322.900	8.896	5901.300
0.615	4896.900	1.577	13655.000	4.054	8946.200	9.101	5870.000
0.694	5336.300	1.593	13937.000	4.259	8538.100	9.369	5807.200
0.757	5870.000	1.640	14188.000	4.448	8287.000	9.685	5807.200
0.820	6372.200	1.640	14439.000	4.606	8004.500	9.969	5775.800
0.868	6780.300	1.656	14691.000	4.842	7847.500	10.205	5775.800
0.915	7282.500	1.704	14879.000	5.110	7722.000	10.410	5713.000
0.962	7753.400	1.782	15004.000	5.363	7596.400	10.615	5744.400
1.025	8192.800	1.845	14722.000	5.615	7470.900		
1.073	8600.900	1.909	14471.000	5.836	7345.300		
1.104	9009.000	2.019	14126.000	6.073	7188.300		
C-40 Concrete							
0.000	0.000	3.915	12031.000	8.783	24589.000	12.664	11620.000
0.164	293.430	4.079	12676.000	8.947	25117.000	12.763	10857.000
0.329	645.540	4.243	13322.000	9.079	25528.000	12.961	10035.000
0.526	938.970	4.375	14026.000	9.309	25822.000	13.125	9331.000
0.691	1291.100	4.507	14495.000	9.605	25528.000	13.289	8568.100
0.888	1643.200	4.638	14906.000	9.803	24883.000	13.355	7863.800
1.020	1995.300	4.737	15493.000	10.033	24237.000	13.553	7100.900
1.217	2406.100	5.000	16080.000	10.197	23709.000	13.882	6514.100

Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]
1.480	2699.500	5.197	16725.000	10.428	23122.000	14.112	5927.200
1.645	3286.400	5.461	17136.000	10.658	22535.000	14.474	5457.700
1.809	3990.600	5.658	17723.000	10.855	21890.000	15.099	5164.300
2.072	4401.400	5.921	18251.000	11.053	21362.000	15.625	4870.900
2.204	4753.500	6.217	18662.000	11.217	20833.000	16.053	4753.500
2.303	5340.400	6.349	19190.000	11.414	20305.000	16.579	4636.200
2.467	6044.600	6.612	19601.000	11.579	19777.000	17.072	4577.500
2.632	6572.800	6.941	20070.000	11.776	19073.000	17.632	4518.800
2.796	7100.900	7.138	20540.000	11.875	18369.000	18.059	4342.700
2.961	7746.500	7.467	21068.000	11.974	17547.000	18.520	4401.400
3.092	8509.400	7.665	21538.000	12.072	16784.000	18.980	4401.400
3.290	9037.600	7.862	22066.000	12.171	15962.000	19.375	4342.700
3.388	9624.400	8.059	22477.000	12.270	15023.000	19.770	4284.000
3.487	10211.000	8.224	23005.000	12.336	14085.000		
3.651	10857.000	8.487	23650.000	12.467	13380.000		
3.750	11444.000	8.651	24237.000	12.599	12441.000		

Accordingly, based on the above points given on table 5.9, the Stress-Strain graph for sample 5 with C-25 and C-40 is drawn in the figure as shown below.

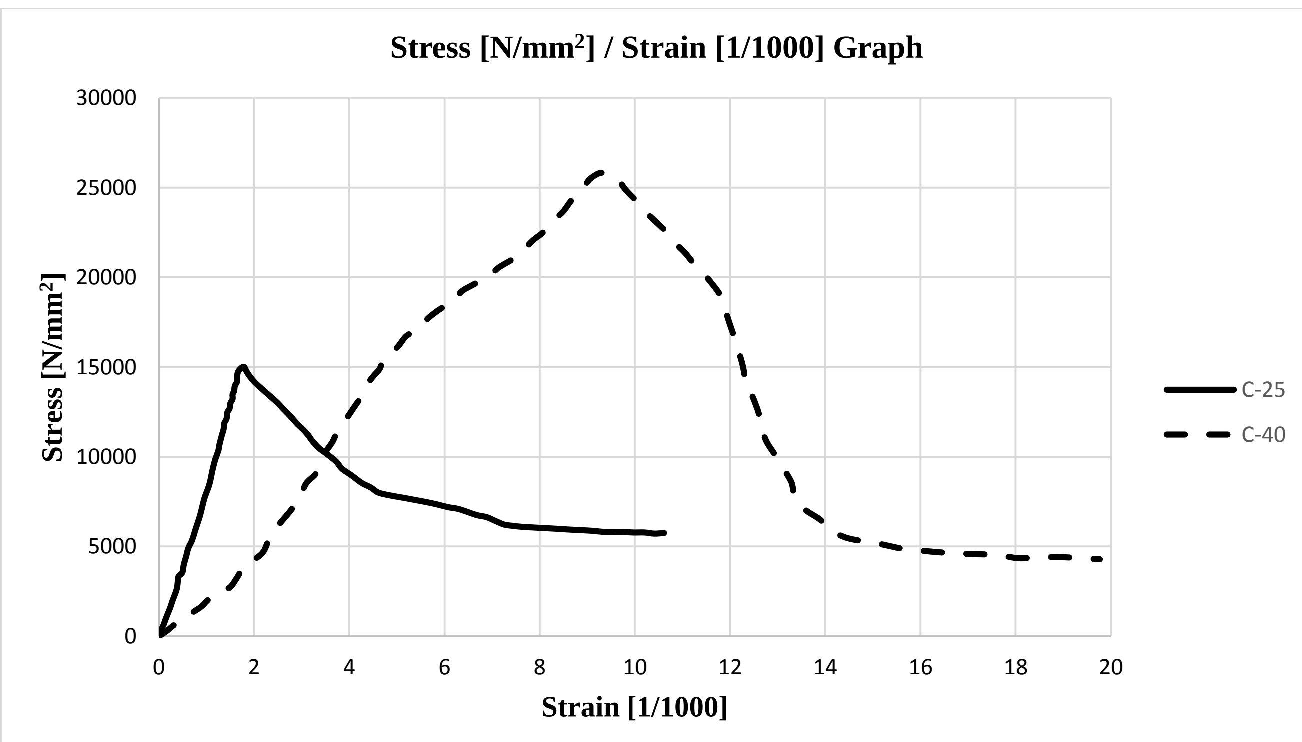


Figure 5.3 Stress-Strain Curve for Sample 5

Table 5.10 Points of Stress-Strain curve for Sample 6

Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]
C-25 Concrete							
0.000	0.000	1.380	11240.000	4.139	18806.000	6.517	3513.000
0.036	387.560	1.416	11870.000	4.284	18419.000	6.681	2738.800
0.127	872.180	1.471	12500.000	4.484	17694.000	6.826	2061.400
0.200	1453.600	1.525	13226.000	4.666	17016.000	7.153	1723.800
0.272	2035.000	1.598	13856.000	4.847	16388.000	7.498	1483.000
0.309	2422.600	1.670	14486.000	5.029	15759.000	7.879	1290.900
0.381	2955.500	1.725	15116.000	5.174	15130.000	8.224	1098.600
0.436	3343.200	1.815	15649.000	5.356	14549.000	8.587	857.900
0.508	3827.700	1.888	16182.000	5.537	13969.000	8.932	762.440
0.563	4312.200	2.015	16860.000	5.646	13582.000	9.295	715.480
0.635	4845.200	2.088	17490.000	5.682	12759.000	9.586	716.650
0.690	5281.200	2.251	18024.000	5.737	12081.000	9.912	621.110
0.781	6008.000	2.396	18654.000	5.755	11307.000	10.366	719.800
0.835	6347.200	2.542	19235.000	5.773	10774.000	10.638	817.750
0.890	6880.100	2.614	19817.000	5.828	10290.000	10.911	1109.400
0.944	7364.600	2.760	20302.000	5.864	9515.200	11.274	1498.300
1.017	7897.600	2.887	20932.000	5.918	8982.700	11.564	1983.700
1.126	8576.000	2.996	21562.000	5.955	8159.600	11.982	2324.400
1.144	9060.300	3.159	22047.000	5.991	7578.700	12.236	2761.200
1.235	9496.500	3.395	21612.000	6.027	6997.700	12.599	3053.300
1.271	9641.900	3.576	20983.000	6.064	6223.000	12.853	3151.100
1.253	9884.000	3.722	20499.000	6.136	5496.900		
1.271	10223.000	3.831	20015.000	6.245	4867.800		
1.307	10611.000	3.958	19532.000	6.390	4093.600		
C-40 Concrete							
0.000	0.000	5.815	11082.000	8.958	21325.000	11.685	4553.200
0.306	156.730	5.926	11705.000	9.264	20858.000	11.740	3774.100
0.696	417.590	6.065	12485.000	9.515	20287.000	11.935	3099.400
1.141	626.670	6.204	13213.000	9.737	19924.000	12.130	2632.400
1.502	835.500	6.315	13888.000	9.876	19613.000	12.352	2113.600
1.836	1096.200	6.454	14512.000	9.960	18938.000	12.714	1854.900
2.226	1253.200	6.482	15136.000	10.071	18159.000	13.076	1596.200

Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]
2.560	1513.900	6.649	15759.000	10.155	17588.000	13.410	1545.200
2.921	1722.700	6.705	16487.000	10.210	16861.000	13.743	1598.100
3.199	1983.300	6.844	17215.000	10.321	16030.000	14.049	1599.000
3.505	2347.800	6.983	18046.000	10.377	15251.000	14.328	1443.900
3.700	2919.800	7.067	18618.000	10.488	14420.000	14.689	1445.000
3.951	3336.100	7.150	19293.000	10.600	13589.000	15.051	1290.200
4.090	3856.000	7.233	19969.000	10.655	12654.000	15.413	1187.300
4.284	4272.100	7.317	20541.000	10.822	11616.000	15.607	1187.900
4.396	4843.900	7.373	21060.000	10.906	10889.000	15.858	1188.600
4.563	5363.800	7.484	21580.000	10.961	10058.000	16.164	1033.700
4.702	5987.600	7.539	22204.000	11.045	9486.400	16.637	1035.000
4.869	6611.500	7.651	22775.000	11.073	9019.000	17.054	984.280
5.008	7339.100	7.679	23295.000	11.156	8447.800	17.527	985.650
5.175	8118.800	7.790	23399.000	11.240	7668.800	18.167	831.650
5.342	8846.600	8.096	23036.000	11.351	6993.800	18.807	885.450
5.481	9522.300	8.346	22570.000	11.490	6007.200		
5.620	10250.000	8.680	21947.000	11.573	5280.200		

Accordingly, based on the above points given on table 5.10, the Stress-Strain graph for sample 5 with C-25 and C-40 is drawn in the figure as shown below.

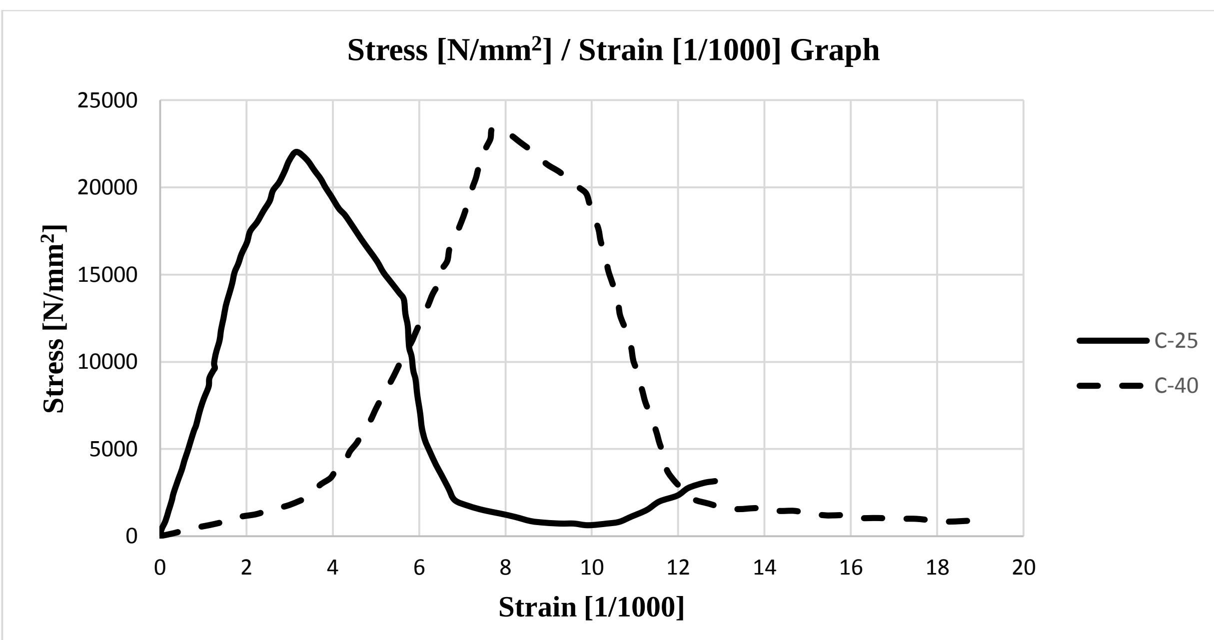


Figure 5.4 Stress-Strain Curve for Sample 6

Table 5.11 Points of Stress-Strain curve for Sample 7

Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]
C-25 Concrete							
0.000	0.000	1.698	5663.600	3.938	13618.000	6.532	5440.900
0.056	254.550	1.829	5886.400	3.994	13936.000	6.700	5059.100
0.131	413.640	1.922	6140.900	4.124	14127.000	6.849	4772.700
0.224	604.550	2.016	6490.900	4.330	14000.000	6.961	4518.200
0.261	827.270	2.165	6745.500	4.442	13650.000	7.129	4390.900
0.355	1050.000	2.258	7190.900	4.535	13332.000	7.316	4136.400
0.429	1368.200	2.426	7413.600	4.647	13014.000	7.540	3850.000
0.467	1654.500	2.482	7700.000	4.740	12664.000	7.708	3722.700
0.579	1940.900	2.594	8081.800	4.871	12409.000	7.894	3595.500
0.653	2163.600	2.725	8400.000	4.964	12027.000	8.118	3468.200
0.709	2481.800	2.762	8781.800	5.039	11741.000	8.324	3372.700
0.802	2704.500	2.837	9068.200	5.095	11423.000	8.529	3245.500
0.840	2927.300	2.930	9418.200	5.151	11105.000	8.790	3181.800
0.896	3054.500	2.986	9672.700	5.207	10723.000	8.958	3086.400
0.952	3277.300	3.079	10023.000	5.263	10691.000	9.182	3022.700
1.008	3595.500	3.173	10373.000	5.300	10277.000	9.387	2927.300
1.101	3786.400	3.210	10691.000	5.394	9831.800	9.649	2800.000
1.157	3977.300	3.303	11009.000	5.468	9259.100	9.873	2768.200
1.213	4200.000	3.378	11264.000	5.543	8877.300	10.115	2736.400
1.288	4486.400	3.453	11645.000	5.655	8431.800	10.451	2672.700
1.362	4645.500	3.527	11964.000	5.785	7954.500	10.731	2640.900
1.418	4804.500	3.621	12282.000	5.916	7445.500	11.142	2609.100
1.512	5059.100	3.714	12664.000	6.028	6936.400	11.515	2577.300
1.549	5218.200	3.733	13045.000	6.177	6395.500	11.944	2481.800
1.642	5472.700	3.845	13300.000	6.364	5790.900	12.467	2322.700
C-40 Concrete							
0.000	0.000	2.351	8889.500	4.253	14396.000	9.063	6982.000
0.150	359.900	2.415	9213.400	4.446	14144.000	9.234	6694.100
0.278	611.830	2.458	9501.300	4.638	13820.000	9.447	6406.200
0.363	863.750	2.479	9861.200	4.809	13568.000	9.682	6190.200
0.470	1079.700	2.544	10113.000	4.959	13316.000	9.875	5902.300
0.577	1403.600	2.586	10509.000	5.130	12992.000	10.110	5722.400
0.663	1727.500	2.629	10761.000	5.344	12704.000	10.260	5470.400
0.748	1871.500	2.672	10905.000	5.515	12308.000	10.495	5218.500
0.855	2159.400	2.736	11229.000	5.750	11985.000	10.687	5038.600

Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]
0.940	2519.300	2.779	11481.000	6.006	11589.000	10.986	4822.600
1.069	2771.200	2.800	11733.000	6.263	11121.000	11.350	4642.700
1.154	3131.100	2.843	12021.000	6.434	10833.000	11.606	4390.700
1.261	3563.000	2.907	12380.000	6.647	10509.000	11.798	4282.800
1.389	3850.900	2.928	12632.000	6.818	10293.000	12.055	4138.800
1.496	4282.800	2.928	12956.000	6.989	10077.000	12.247	4066.800
1.582	4750.600	3.078	13244.000	7.118	9753.200	12.440	3994.900
1.689	5182.500	3.121	13640.000	7.310	9645.200	12.632	3922.900
1.710	5362.500	3.163	14000.000	7.417	9429.300	12.803	3814.900
1.774	5794.300	3.249	14360.000	7.609	9141.400	13.017	3742.900
1.860	6226.200	3.313	14612.000	7.802	8817.500	13.209	3706.900
1.945	6658.100	3.356	14936.000	8.079	8529.600	13.466	3599.000
2.009	7018.000	3.505	15152.000	8.272	8205.700	13.744	3491.000
2.116	7413.900	3.698	15188.000	8.486	7917.700	14.043	3419.000
2.180	7917.700	3.912	14936.000	8.657	7629.800	14.299	3275.100
2.266	8529.600	4.082	14684.000	8.892	7269.900	14.791	3095.100

Accordingly, based on the above points given on table 5.11, the Stress-Strain graph for sample 5 with C-25 and C-40 is drawn in the figure as shown below.

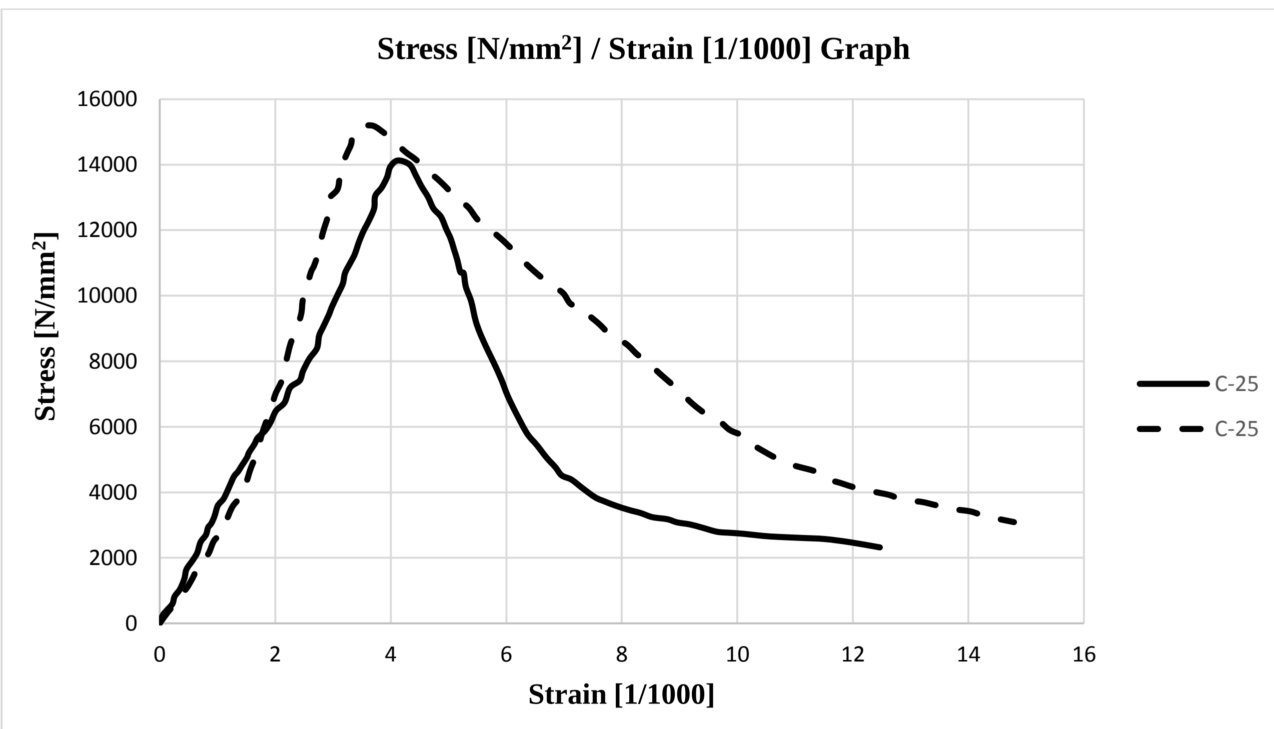


Figure 5.5 Stress-Strain Curve for Sample 7

Table 5.12 Points of Stress-Strain curve for Sample 11

Strain [1/1000]	**Stress [N/mm²]**	**Strain [1/1000]**	**Stress [N/mm²]**	**Strain [1/1000]**	**Stress [N/mm²]**	**Strain [1/1000]**	**Stress [N/mm²]**
C-25 Concrete							
0.000	0.000	8.333	5961.220	12.388	19040.565	16.049	4198.142
0.366	99.917	8.634	6556.024	12.587	18446.997	16.182	3901.440
0.666	249.174	8.901	7200.250	12.818	17754.500	16.381	3654.408
0.866	348.678	9.169	7794.972	12.917	17210.190	16.547	3357.788
1.232	448.595	9.303	8438.869	13.015	16566.869	16.779	3160.344
1.598	499.006	9.471	9033.344	13.113	15824.538	16.978	2863.807
1.832	648.098	9.705	9479.468	13.211	14983.196	17.211	2666.363
2.165	698.427	9.872	10024.437	13.343	14191.442	17.443	2419.413
2.464	798.179	10.006	10420.808	13.474	13548.204	17.642	2172.381
2.731	947.354	10.174	10866.767	13.606	12756.450	17.841	2024.360
3.097	997.765	10.342	11461.242	13.671	12063.541	18.107	1826.998
3.530	1097.846	10.543	12154.809	13.836	11568.901	18.340	1679.059
3.930	1296.856	10.677	12848.211	13.901	10875.993	18.639	1481.779
4.363	1396.937	10.846	13640.707	14.033	10331.765	18.838	1432.768
4.829	1596.111	11.014	14581.718	14.165	9688.526	19.038	1334.252
5.295	1844.790	11.115	15077.017	14.263	8946.195	19.337	1235.983
5.729	2142.892	11.216	15572.317	14.362	8500.895	19.503	1186.890
6.062	2490.253	11.317	16067.616	14.493	7857.657	19.636	1137.714
6.595	2887.612	11.418	16612.421	14.658	7115.490	19.836	1138.208
6.896	3333.901	11.486	17157.143	14.823	6521.839	20.002	1039.610
7.197	3829.694	11.620	17801.040	15.022	6027.281	20.135	1039.939
7.430	4275.818	11.688	18395.267	15.220	5631.734	20.202	1040.104
7.598	4622.766	11.789	18989.577	15.486	5137.341	20.335	990.928
7.798	5068.808	11.923	19484.959	15.651	4741.711	20.468	941.752
8.099	5564.601	12.156	19386.525	15.850	4445.174	20.601	892.577
C-40 Concrete							
0.000	0.000	3.190	10224.586	5.880	24468.085	9.868	13238.771
0.159	295.508	3.296	10697.400	5.987	25295.508	9.973	12234.043
0.292	531.915	3.403	11288.416	5.987	25118.203	10.052	11288.416
0.478	827.423	3.483	11820.331	6.120	25945.626	10.130	10460.993
0.637	1004.728	3.536	12470.449	6.227	26418.440	10.156	9810.875
0.796	1182.033	3.669	13002.364	6.360	27068.558	10.235	8865.248
0.982	1654.846	3.670	13416.076	6.466	27364.066	10.498	7919.622
1.168	1832.151	3.776	13888.889	6.863	27245.863	10.710	7092.199
1.327	2127.660	3.856	14302.600	7.102	27127.660	10.868	6323.877

Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]
1.539	2364.066	3.963	14775.414	7.366	26418.440	11.132	5673.759
1.698	2777.778	4.016	15366.430	7.603	25591.017	11.449	5082.742
1.752	3073.286	4.176	16016.548	7.788	24822.695	11.819	4609.929
1.911	3486.998	4.256	16725.768	7.973	24113.475	12.163	4196.217
1.991	4078.014	4.416	17257.683	8.157	23522.459	12.507	3900.709
2.124	4491.726	4.522	17730.496	8.342	22754.137	12.931	3664.303
2.257	5082.742	4.602	18203.310	8.527	21985.816	13.408	3368.794
2.364	5555.556	4.709	18794.326	8.738	21217.494	13.858	3132.388
2.417	6087.470	4.868	19148.936	8.949	20390.071	14.308	2955.083
2.550	6619.385	5.054	19680.851	9.107	19739.953	14.731	2777.778
2.657	7210.402	5.187	20212.766	9.318	18971.631	15.129	2659.574
2.737	7742.317	5.320	20921.986	9.476	18262.411	15.579	2600.473
2.843	8156.028	5.427	21749.409	9.581	17316.785	16.003	2364.066
2.950	8628.842	5.507	22399.527	9.633	15957.447	16.506	2186.761
3.003	9160.757	5.640	22931.442	9.738	15070.922	17.141	2009.456
3.083	9692.671	5.747	23758.865	9.790	14184.397	17.989	1654.846

Accordingly, based on the above points given on table 5.12, the Stress-Strain graph for sample 5 with C-25 and C-40 is drawn in the figure as shown below.

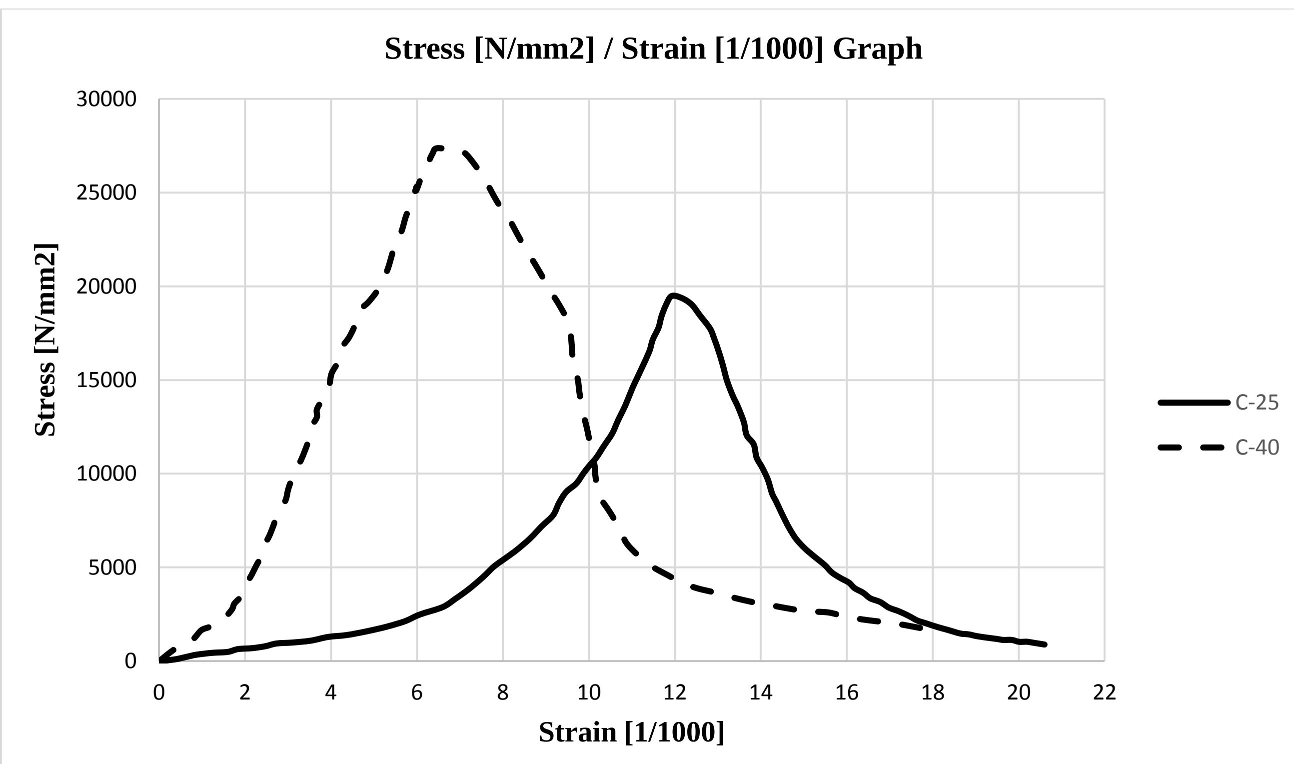


Figure 5.6 Stress-Strain Curve for Sample 11

Table 5.13 Points of Stress-Strain curve for Sample 12

Strain [1/1000]	Stress [N/mm²]	Strain [1/1000]	Stress [N/mm²]	Strain [1/1000]	Stress [N/mm²]	Strain [1/1000]	Stress [N/mm²]
C-25 Concrete							
0.000	0.000	1.285	11711.230	3.454	20106.952	5.402	5401.070
0.060	320.856	1.325	12459.893	3.514	19518.717	5.582	4973.262
0.141	695.187	1.386	13208.556	3.594	19090.909	5.763	4385.027
0.221	1016.043	1.426	14010.695	3.635	18609.626	5.984	3903.743
0.301	1497.326	1.466	14491.979	3.695	18181.818	6.165	3582.888
0.361	1978.610	1.506	15240.642	3.755	17647.059	6.345	3368.984
0.482	2459.893	1.506	15882.353	3.815	17112.299	6.506	3101.604
0.502	2834.225	1.566	16363.636	3.855	16577.540	6.767	2834.225
0.542	3315.508	1.627	17326.203	3.916	15989.305	6.988	2620.321
0.622	3796.791	1.647	17860.963	3.976	15454.545	7.209	2406.417
0.683	4224.599	1.687	18395.722	4.056	14812.834	7.470	2245.989
0.703	4705.882	1.727	18930.481	4.116	14171.123	7.731	2085.561
0.763	5133.690	1.747	19518.717	4.157	13636.364	8.052	1978.610
0.783	5454.545	1.767	20106.952	4.237	13048.128	8.373	1871.658
0.823	6042.781	1.867	20748.663	4.297	12566.845	8.735	1764.706
0.904	6470.588	1.928	21336.898	4.357	12032.086	8.996	1711.230
0.944	7005.348	2.008	21978.610	4.438	11443.850	9.257	1657.754
0.984	7540.107	2.068	22620.321	4.538	10588.235	9.618	1711.230
1.044	8128.342	2.229	22245.989	4.639	9786.096	9.940	1764.706
1.064	8663.102	2.390	22085.561	4.759	9090.909	10.201	1711.230
1.104	9144.385	2.631	21657.754	4.839	8502.674	10.482	1711.230
1.145	9625.668	2.831	21390.374	4.960	7860.963	10.884	1711.230
1.165	10106.952	2.972	21122.995	5.060	7272.727	11.165	1550.802
1.205	10641.711	3.133	20802.139	5.141	6631.016	11.486	1550.802
1.265	11283.422	3.273	20481.283	5.221	5989.305	11.727	1443.850
C-40 Concrete							
0.000	0.000	1.120	19642.857	4.340	18526.786	7.400	1339.286
0.080	669.643	1.180	20461.310	4.460	17485.119	7.540	1264.881
0.180	1339.286	1.220	21354.167	4.580	16815.476	7.720	1264.881
0.240	1860.119	1.280	22247.024	4.620	15997.024	7.880	1190.476
0.280	2455.357	1.280	23065.476	4.720	15178.571	8.060	1190.476
0.320	3050.595	1.320	23809.524	4.780	14508.929	8.260	1116.071
0.380	3869.048	1.360	24702.381	4.880	13839.286	8.440	1116.071
0.440	4687.500	1.420	25595.238	4.960	13244.048	8.620	1116.071

Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]
0.500	5431.548	1.440	26711.310	5.040	12574.405	8.800	1116.071
0.520	6026.786	1.520	27306.548	5.100	11458.333	8.940	1041.667
0.560	6845.238	1.540	28497.024	5.160	10639.881	9.120	1041.667
0.600	7663.690	1.800	28348.214	5.220	9747.024	9.280	967.262
0.640	8556.548	2.040	27976.190	5.360	8779.762	9.420	818.452
0.720	9598.214	2.380	27678.571	5.420	7812.500	9.580	818.452
0.720	10714.286	2.620	27455.357	5.580	6398.810	9.780	818.452
0.740	11383.929	2.860	27008.929	5.620	5282.738	9.960	892.857
0.800	11979.167	3.120	26562.500	5.820	4166.667	10.200	818.452
0.820	12946.429	3.460	26413.690	6.020	3348.214	10.300	818.452
0.860	13839.286	3.600	25446.429	6.140	2827.381	10.480	818.452
0.880	14434.524	3.680	24702.381	6.260	2380.952	10.700	818.452
0.920	15178.571	3.760	23809.524	6.400	1934.524	10.980	818.452
1.000	16071.429	3.920	22619.048	6.600	1785.714	11.260	818.452
1.000	17038.690	4.040	21577.381	6.740	1785.714	11.440	669.643
1.060	17931.548	4.160	20461.310	6.980	1562.500	11.700	595.238
1.080	18750.000	4.260	19494.048	7.200	1339.286	12.100	595.238

Accordingly, based on the above points given on table 5.13, the Stress-Strain graph for sample 5 with C-25 and C-40 is drawn in the figure as shown below.

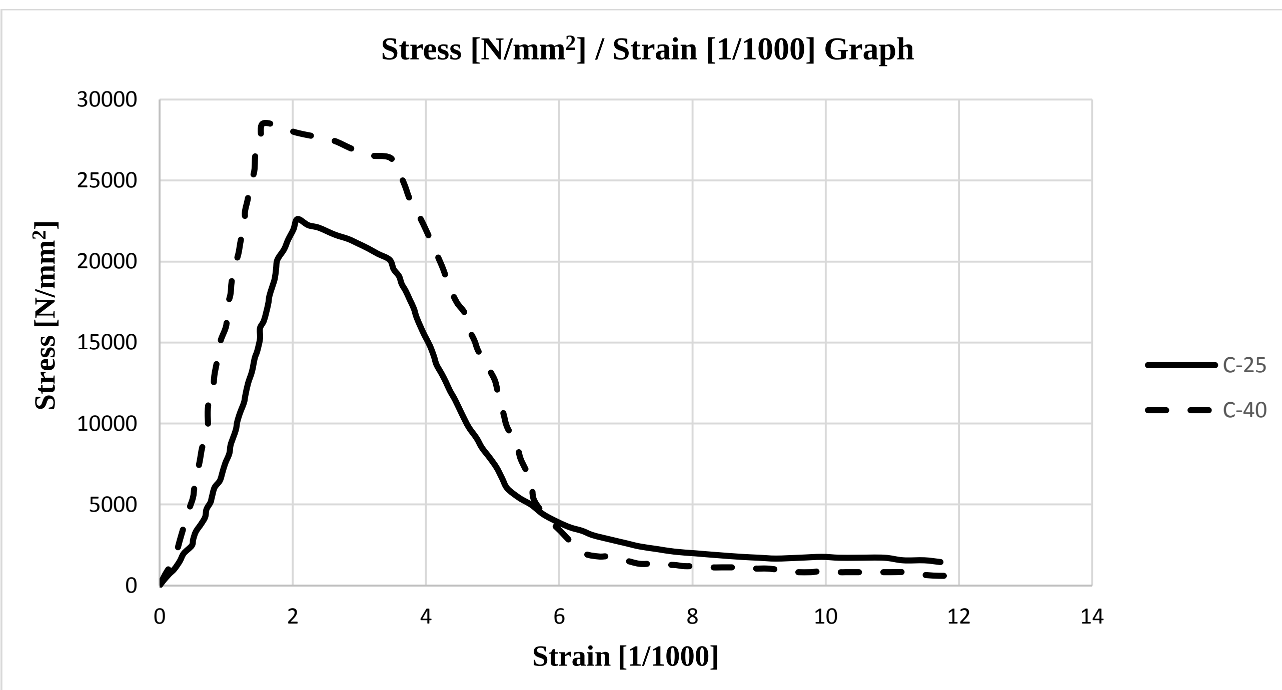


Figure 5.7 Stress-Strain Curve for Sample 12

Table 5.14 Points of Stress-Strain curve for Sample 15

Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]
C-25 Concrete							
0.000	0.000	1.824	5158.690	4.036	6931.990	6.809	2277.078
0.024	181.360	1.921	5400.504	4.134	6670.025	7.027	2176.322
0.097	362.720	1.994	5722.922	4.182	6508.816	7.198	2015.113
0.170	564.232	2.018	6085.642	4.255	6267.003	7.416	1914.358
0.219	806.045	2.091	6327.456	4.353	6025.189	7.660	1793.451
0.267	987.406	2.140	6609.572	4.353	5904.282	7.878	1632.242
0.267	1168.766	2.164	6811.083	4.426	5763.224	8.146	1491.184
0.316	1249.370	2.286	7113.350	4.474	5622.166	8.462	1370.277
0.389	1390.428	2.359	7335.013	4.498	5481.108	8.827	1249.370
0.511	1571.788	2.383	7536.524	4.571	5239.295	9.143	1128.463
0.608	1773.300	2.407	7778.338	4.596	5057.935	9.410	1027.708
0.705	1934.509	2.456	8000.000	4.766	4755.668	9.678	967.254
0.802	2176.322	2.505	8261.965	4.863	4534.005	10.018	906.801
0.875	2317.380	2.626	8544.081	4.985	4352.645	10.310	846.348
0.948	2518.892	2.772	8765.743	5.082	4191.436	10.626	785.894
1.021	2700.252	2.894	8967.254	5.277	3949.622	11.015	785.894
1.167	2982.368	3.112	8765.743	5.398	3788.413	11.404	765.743
1.240	3224.181	3.234	8604.534	5.471	3607.053	11.793	705.290
1.313	3425.693	3.380	8443.325	5.593	3405.542	12.109	685.139
1.362	3647.355	3.502	8261.965	5.812	3183.879	12.426	685.139
1.435	3909.320	3.647	8060.453	5.909	3002.519	12.742	664.987
1.556	4130.982	3.745	7778.338	6.055	2821.159	13.131	644.836
1.653	4352.645	3.818	7596.977	6.249	2680.101	13.690	604.534
1.678	4654.912	3.891	7395.466	6.444	2498.741	14.517	523.929
1.751	4876.574	3.915	7153.652	6.663	2397.985	16.438	443.325
C-40 Concrete							
0.000	0.000	1.054	5774.525	2.968	9255.573	5.720	1787.597
0.043	196.251	1.097	6054.809	3.097	9032.000	5.914	1620.304
0.065	420.426	1.140	6307.082	3.226	8752.404	6.172	1425.258
0.065	672.527	1.204	6615.463	3.290	8444.539	6.366	1257.966
0.108	868.778	1.247	6951.770	3.376	8164.771	6.452	1174.276
0.108	1092.867	1.312	7372.196	3.484	7801.056	6.817	1063.694
0.151	1401.163	1.355	7680.492	3.591	7409.329	7.183	925.101
0.215	1569.488	1.441	8129.015	3.699	7101.636	7.505	842.358

Strain [1/1000]	Stress [N/mm²]	Strain [1/1000]	Stress [N/mm²]	Strain [1/1000]	Stress [N/mm²]	Strain [1/1000]	Stress [N/mm²]
0.237	1849.686	1.441	8437.138	3.763	6765.760	8.065	732.551
0.323	2046.109	1.548	8801.714	3.892	6374.120	8.366	677.733
0.366	2214.348	1.527	9109.751	4.000	5982.393	8.602	650.669
0.409	2438.610	1.570	9418.047	4.108	5562.655	8.903	623.862
0.452	2662.872	1.656	9754.525	4.237	5143.003	9.183	568.959
0.538	2943.328	1.699	10118.843	4.366	4807.385	9.484	542.152
0.602	3195.687	1.720	10371.030	4.430	4555.543	9.785	487.335
0.624	3391.851	1.763	10707.337	4.473	4247.592	10.151	488.798
0.688	3644.210	1.806	11071.654	4.559	4051.857	10.452	461.991
0.710	3896.397	1.871	11380.036	4.645	3828.112	10.839	407.518
0.774	4064.723	2.151	11241.099	4.774	3688.572	11.269	381.228
0.796	4316.910	2.344	11101.817	4.860	3408.804	11.613	382.605
0.882	4569.355	2.495	10794.296	5.054	3157.478	12.129	328.648
0.925	4793.616	2.559	10514.442	5.204	2877.968	12.559	330.369
0.989	4961.942	2.667	10178.738	5.333	2542.350	12.946	303.907
0.968	5213.957	2.839	9815.281	5.441	2290.680	13.527	306.230
1.011	5494.241	2.946	9563.610	5.613	2011.256	15.118	256.576

Accordingly, based on the above points given on table 5.14, the Stress-Strain graph for sample 5 with C-25 and C-40 is drawn in the figure as shown below.

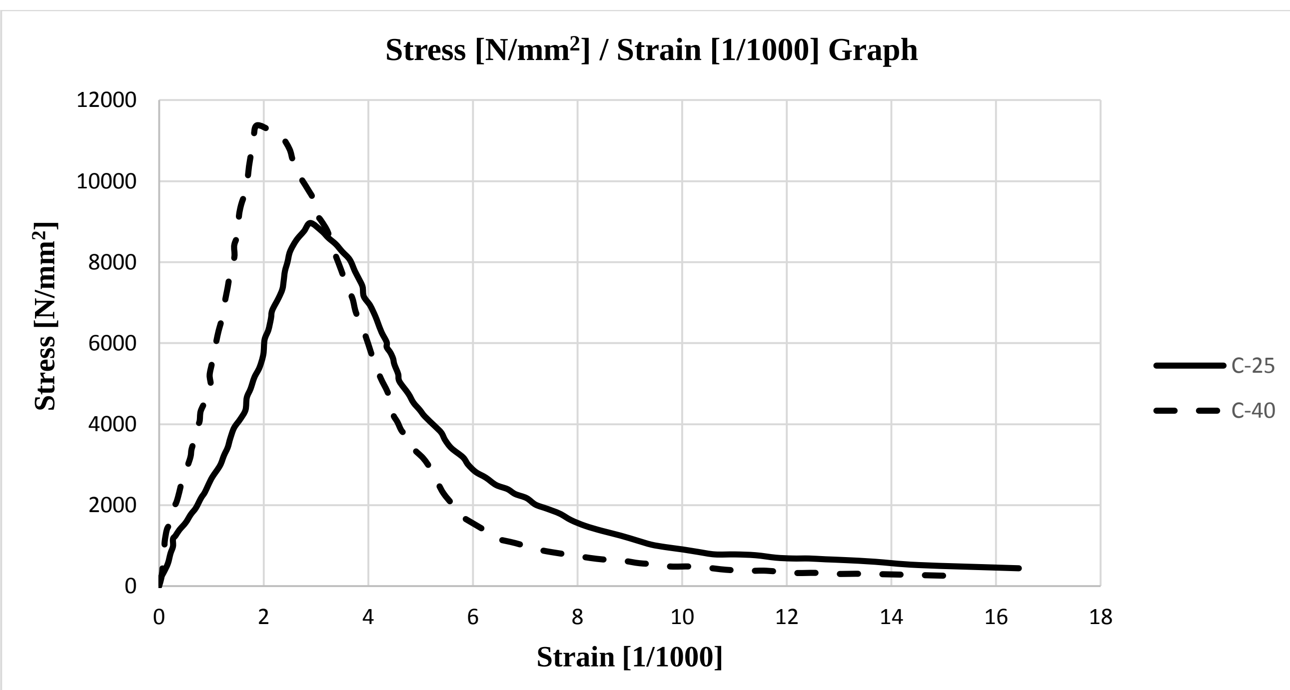


Figure 5.8 Stress-Strain Curve for Sample 15

Table 5.15 Points of Stress-Strain curve for Sample 16

Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]
C-25 Concrete							
0.000	0.000	1.012	3471.707	2.383	7158.891	5.714	1288.286
0.042	161.900	1.054	3633.606	2.467	6942.845	5.967	1179.991
0.042	305.858	1.117	3813.474	2.593	6708.749	6.325	1089.556
0.105	413.746	1.160	3939.383	2.678	6474.707	6.620	999.202
0.169	611.608	1.181	4047.326	2.783	6312.618	6.895	926.871
0.190	719.550	1.181	4191.284	2.867	6006.597	7.127	926.573
0.232	899.445	1.223	4335.189	2.931	5790.577	7.401	872.236
0.232	989.419	1.286	4479.067	3.057	5556.482	7.675	835.894
0.232	1061.399	1.349	4676.929	3.163	5232.439	8.033	799.443
0.253	1151.346	1.370	4928.830	3.268	4980.375	8.286	781.123
0.295	1277.256	1.434	5144.687	3.373	4692.322	8.602	762.722
0.337	1403.165	1.455	5378.593	3.500	4512.211	8.834	744.429
0.380	1547.070	1.560	5594.396	3.563	4206.217	9.066	726.136
0.422	1654.985	1.623	5810.253	3.711	3900.115	9.361	725.756
0.506	1726.856	1.602	6026.218	3.816	3666.046	9.636	725.404
0.569	1888.728	1.666	6224.080	3.880	3378.047	9.889	689.089
0.633	2086.591	1.750	6475.900	4.027	3053.950	10.205	652.693
0.675	2230.495	1.771	6673.816	4.133	2819.881	10.437	670.390
0.717	2410.390	1.834	6925.663	4.238	2657.792	10.753	615.999
0.759	2536.299	1.855	7195.559	4.364	2477.681	11.006	615.673
0.843	2662.155	1.919	7375.426	4.575	2279.466	11.364	615.213
0.843	2788.119	1.982	7591.283	4.723	2045.343	11.807	614.644
0.907	2949.991	2.003	7771.204	4.913	1793.171	12.377	559.927
0.949	3129.886	2.235	7554.968	5.123	1612.952	13.283	504.777
0.991	3291.785	2.319	7374.911	5.440	1450.592	14.063	467.785
C-40 Concrete							
0.000	0.000	2.141	5798.526	4.034	9410.319	6.751	2555.283
0.055	245.700	2.196	5995.086	4.117	9287.469	7.026	2309.582
0.165	466.830	2.250	6167.076	4.254	9041.769	7.300	2039.312
0.247	663.391	2.305	6486.486	4.391	8796.069	7.465	1769.042
0.357	1130.221	2.360	6756.757	4.501	8501.229	7.739	1547.912
0.439	1326.781	2.415	6953.317	4.583	8230.958	8.096	1425.061
0.494	1547.912	2.470	7272.727	4.693	7936.118	8.370	1302.211
0.576	1744.472	2.525	7469.287	4.830	7714.988	8.672	1203.931
0.686	1965.602	2.580	7714.988	4.913	7469.287	9.029	1253.071

Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]	Strain [1/1000]	Stress [N/mm^2]
0.796	2162.162	2.580	7985.258	5.022	7199.017	9.441	1253.071
0.906	2358.722	2.662	8206.388	5.077	6928.747	9.743	1228.501
1.015	2604.423	2.717	8476.658	5.269	6609.337	10.017	1253.071
1.153	2776.413	2.799	8746.929	5.407	6314.496	10.346	1253.071
1.262	2997.543	2.827	8992.629	5.489	6068.796	10.895	1203.931
1.317	3243.243	2.882	9213.759	5.599	5798.526	11.362	1081.081
1.427	3464.373	2.964	9484.029	5.708	5528.256	11.938	1007.371
1.564	3660.934	3.019	9705.160	5.818	5233.415	12.487	884.521
1.619	3906.634	3.019	9877.150	5.928	4889.435	13.118	810.811
1.647	4152.334	3.101	10098.280	6.038	4692.875	13.777	737.101
1.756	4348.894	3.184	10294.840	6.202	4250.614	14.298	663.391
1.839	4594.595	3.266	10466.830	6.312	3955.774	15.012	638.821
1.894	4864.865	3.431	10270.270	6.395	3734.644	15.671	589.681
1.949	5110.565	3.623	10147.420	6.449	3513.514	16.247	589.681
2.031	5307.125	3.815	9926.290	6.559	3243.243	16.796	540.541
2.058	5601.966	3.925	9680.590	6.696	2899.263	17.345	491.400

Accordingly, based on the above points given on table 5.15, the Stress-Strain graph for sample 5 with C-25 and C-40 is drawn in the figure as shown below.

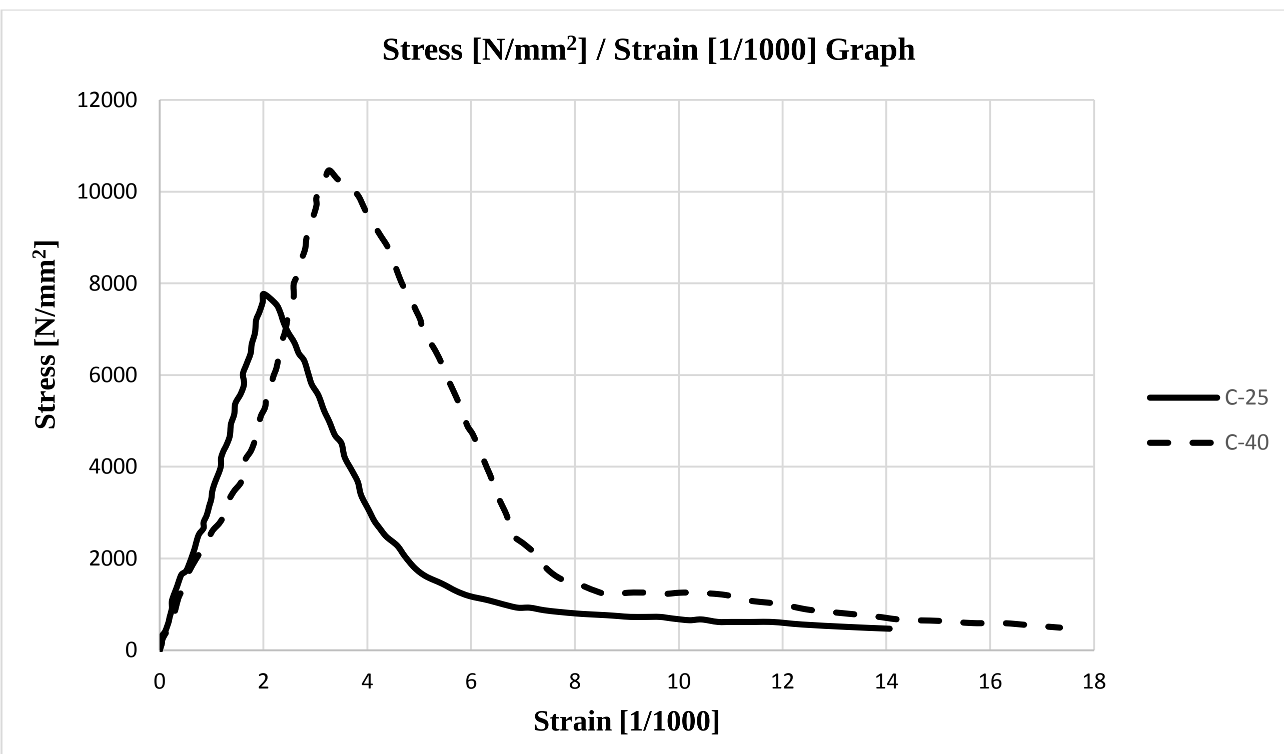


Figure 5.9 Stress-Strain Curve for Sample 16

As clearly shown on the above figures for stress-strain graph starting from figure 5.1 to 5.9 the maximum stress value for all case is high for concrete mix with concrete grade enhancer admixture (C-40 concrete) in compare with concrete mix without admixture (C-25 concrete). This implies the ultimate load capacity for concrete mix with admixture is higher than the concrete nix without concrete grade enhancer admixture. Moreover, the deformation length of concrete with admixture is higher than that of a concrete mix without admixture.

This proofs concrete mix with concrete grade enhancer admixture (C-40 concrete) is more ductile than a concrete mix without admixture(C-25 concrete).

5.2 INTERPRETATION OF STRUCTURAL DESIGN RESULT

One of the mechanism to investigate the effect of concrete grade enhancer admixture on structural design reinforced concrete structures is done using sample structural design in addition to laboratory test. Basically laboratory test is conducted to know the effect of concrete grade enhancer admixture on concrete performance. Whereas the main aim of doing sample structural design is to know the effect of introducing concrete grade enhancer admixture in related to structural design cost and other structural design related parameters.

5.2.1 INTERPRETATION OF STRUCTURAL DESIGN COST

In this section structural design cost of all buildings using both C-25 concrete (concrete without concrete grade enhancer admixture) and C-40 (concrete with concrete grade enhancer admixture) is done to know the effect of introducing concrete grade enhancer admixture on concrete mix.

Cost analysis is done for all civil works in which their quantity is affected by structural design. Some of the major civil works that are highly affected by structural design of a building are pit excavation for footings and foundation columns, cart away, formwork, concrete work and rebar work for footings, beams, columns, staircases and slabs. Moreover, civil works like floor finish, painting and block works also affected by structural design. But here in this research cost analysis is done for major civil works that are highly affected by structural design.

5.2.1.1 INTERPRETATION OF STRUCTURAL DESIGN COST FOR G+2 BUILDING

Table 5.16 Interpretation of structural design cost for G+2 building

SUMMARY OF SAMPLE STRUCTURAL DESIGN COST FOR G+2 BUILDING				
Work item description	**Cost with C-25 Concrete**	**Cost with C-40 Concrete**	**Cost reduced**	**Cost reduction (%)**
A. SUBSTRUCTURE WORK				
1.A.1 EXCAVATION & EARTH WORKS	**187,222.31**	**171,420.48**	**15,801.84**	**8.44%**
1.A.1.1 Pit excavation (0-1.5m depth)	39,029.14	34,895.87	4,133.27	10.59%
1.A.1.2 Pit excavation (1.5-3m depth)	-	-	-	-
1.A.1.3 Backfill around footing	13,283.38	11,041.88	2,241.50	16.87%
1.A.1.4 Backfill around foundation column	87,421.42	83,023.48	4,397.94	5.03%
1.A.1.5 Cart away	47,488.37	42,459.25	5,029.12	10.59%
1.A.2 CONCRETE WORKS	**780,546.14**	**684,768.21**	**95,777.93**	**12.27%**
1.A.2.1 Lean concrete				
a. Under footing	9,281.45	8,584.36	697.09	7.51%
b. Under grade beam	6,799.53	5,520.77	1,278.76	18.81%
1.A.2.2 Reinforced concrete				
a. Footing	145,011.07	136,057.80	8,953.27	6.17%
b. Foundation column	16,688.38	9,848.99	6,839.39	40.98%
c. Grade beam	84,580.58	71,422.99	13,157.59	15.56%
1.A.2.3 Formwork				
a. Footing	26,484.58	21,695.04	4,789.55	18.08%
b. Foundation column	13,618.26	9,657.13	3,961.13	29.09%
c. Grade beam	53,249.86	47,214.43	6,035.42	11.33%
1.A.2.4 Reinforcement work				
a. Footing	220,641.29	208,337.87	12,303.42	5.58%
b. Foundation column	204,191.15	166,428.82	37,762.33	18.49%
TOTAL A………………...…………………	**967,768.46**	**856,188.69**	**111,579.77**	**11.53%**
B. SUPER-STRUCTURE				
1.B.1 CONCRETE WORKS	**1,910,948.12**	**1,814,010.52**	**96,937.60**	**5.07%**
1.B.1.1 Reinforced Concrete				
a. Sample Elevation Column	73,359.47	39,865.94	33,493.54	45.66%
b. Sample Staircase	12,391.47	13,576.79	-1,185.32	-9.57%
c. Sample Floor Beam	53,871.28	41,222.81	12,648.47	23.48%
d. Sample Floor Slab	369,047.62	444,108.94	-75,061.3	-20.34%
1.B.1.2 Formwork				
a. Sample Elevation Column	53,316.96	37,951.41	15,365.56	28.82%
b. Sample Staircase	6,418.02	6,292.76	125.26	1.95%
c. Sample Floor Beam	50,189.24	40,493.75	9,695.49	19.32%
d. Sample Floor Slab	211,585.09	211,585.09	-	-
1.B.1.3 Reinforcement work				
a. Sample Elevation Column	344,355.30	259,206.96	85,148.34	24.73%
b. Sample Floor Beam	117,221.00	110,188.34	7,032.66	6.00%
c. Sample Floor Slab	590,552.99	582,256.64	8,296.35	1.40%
d. Sample Floor Staircase	28,639.67	27,261.10	1,378.57	4.81%

SUMMARY OF SAMPLE STRUCTURAL DESIGN COST FOR G+2 BUILDING				
Work item description	**Cost with C-25 Concrete**	**Cost with C-40 Concrete**	**Cost reduced**	**Cost reduction (%)**
1.B.2 FINISHING WORK	**66,701.99**	**50,848.16**	**15,853.83**	**23.77%**
1.B.2.1 Plastering				
a. Sample Elevation Column	31,241.98	22,238.27	9,003.71	28.82%
b. Sample Floor Beam	35,460.01	28,609.89	6,850.12	19.32%
1.B.3 PAINTING	**22,052.32**	**16,810.89**	**5,241.43**	**23.77%**
1.B.3.1 Plastic paint				
a. Sample Elevation Column	10,328.90	7,352.18	2,976.71	28.82%
b. Sample Floor Beam	11,723.42	9,458.70	2,264.72	19.32%
TOTAL B…………………………………	**1,999,702.42**	**1,881,669.57**	**118,032.85**	**5.90%**
TOTAL A+B……………………….………..…	**2,967,470.88**	**2,737,858.26**	**229,612.62**	**7.74%**
15% VAT………………….……………..…	**445,120.63**	**410,678.74**	**34,441.89**	**7.74%**
GRAND TOTAL……………......………..	**3,412,591.51**	**3,148,536.99**	**264,054.52**	**7.74%**

As clearly shown on table 5.16 the total structural design cost is reduced by 7.74% for structural design using C-40 concrete (Concrete with concrete enhancer admixture); almost all costs for structural design related civil works are reduced. However, cost of reinforced concrete work for staircase and slab is increased by 9.57% (1,185.32 birr) and 20.34% (75,061.3 birr) respectively. On other hand cost of reinforcement work for staircase and slab is reduced by 4.48% (1,372.57 birr) and 1.4% (8,296.35 birr) respectively. On such fact the total cost of slab is increased by 66,764.95 birr whereas the total cost of staircase is reduced by 187.25 birr. This shows that using concrete grade enhancer admixture for staircase and slab is not significantly reduced structural design cost rather it increase cost of reinforced concrete work. Moreover, since the slab thickness is the same for both type of designs (i.e structural design using C-25 & C-40 concretes), the slab design doesn't create any effect on structural design of beams, column and foundations. Having such indication structural design cost will be more reduced to 9.99% if the slab is designed using C-25 concrete.

Thus, design of slab using C-25 concrete (concrete without concrete grade enhancer admixture) is better than design of slab using C-40 concrete (concrete with concrete grade enhancer admixture) for G+2 building unless lesser thickness of slab is used for building designed using C-40 concrete.

5.2.1.2 INTERPRETATION OF STRUCTURAL DESIGN COST FOR G+7 BUILDING

Table 5.17 Interpretation of structural design cost for G+7 building

SUMMARY OF SAMPLE STRUCTURAL DESIGN COST FOR G+7 BUILDING				
Work Item description	**Cost with C-25 Concrete**	**Cost with C-40 Concrete**	**Cost reduced**	**Cost reduction (%)**
A. SUBSTRUCTURE WORK				
1.A.1 EXCAVATION & EARTH WORKS	**900,161.37**	**831,574.13**	**68,587.24**	**7.62%**
1.A.1.1 Pit excavation (0-1.5m depth)	70,523.56	66,095.30	4,428.26	6.28%
1.A.1.2 Pit excavation (1.5-3m depth)	132,650.32	118,630.24	14,020.08	10.57%
1.A.1.3 Backfill around footing	34,706.45	29,492.85	5,213.61	15.02%
1.A.1.4 Backfill around foundation column	438,068.20	413,159.14	24,909.06	5.69%
1.A.1.5 Cart away	224,212.84	204,196.61	20,016.23	8.93%
1.A.2 CONCRETE WORKS	**2,979,152.73**	**2,561,906.82**	**417,245.90**	**14.01%**
1.A.2.1 Lean concrete				
a. Under footing	28,219.66	26,173.10	2,046.56	7.25%
b. Under grade beam	7,794.47	6,553.15	1,241.32	15.93%
1.A.2.2 Reinforced concrete				
a. Footing	720,050.37	716,288.16	3,762.21	0.52%
b. Foundation column	87,738.68	69,200.67	18,538.01	21.13%
c. Grade beam	108,861.43	96,298.43	12,563.00	11.54%
1.A.2.3 Formwork				
a. Footing	75,464.17	63,445.23	12,018.94	15.93%
b. Foundation column	42,032.77	32,800.85	9,231.93	21.96%
c. Grade beam	58,764.33	52,576.55	6,187.78	10.53%
1.A.2.4 Reinforcement work				
a. Footing	1,114,185.89	1,011,289.99	102,895.90	9.24%
b. Foundation column	736,040.96	487,280.70	248,760.26	33.80%
TOTAL A……………………………………	**3,879,314.10**	**3,393,480.96**	**485,833.14**	**12.52%**
B. SUPER-STRUCTURE				
1.B.1 CONCRETE WORKS	**2,530,479.08**	**2,201,110.05**	**329,369.03**	**13.02%**
1.B.1.1 Reinforced Concrete				
a. Sample Elevation Column	174,933.21	138,001.16	36,932.06	21.11%
b. Sample Staircase	12,876.62	13,576.79	-700.17	-5.44%
c. Sample Floor Beam	72,961.44	64,303.18	8,658.26	11.87%
d. Sample Floor Slab	418,253.97	444,108.94	-25,854.98	-6.18%
1.B.1.2 Formwork				
a. Sample Elevation Column	83,519.22	65,555.75	17,963.47	21.51%
b. Sample Staircase	6,418.02	6,292.76	125.26	1.95%
c. Sample Floor Beam	56,348.39	50,360.42	5,987.97	10.63%
d. Sample Floor Slab	212,871.20	212,338.27	532.93	0.25%
1.B.1.3 Reinforcement work				
a. Sample Elevation Column	791,689.99	485,501.41	306,188.59	38.68%
b. Sample Floor Beam	131,978.65	111,553.64	20,425.01	15.48%
c. Sample Floor Slab	539,942.80	582,256.64	-42,313.84	-7.84%

SUMMARY OF SAMPLE STRUCTURAL DESIGN COST FOR G+7 BUILDING				
Work Item description	**Cost with C-25 Concrete**	**Cost with C-40 Concrete**	**Cost reduced**	**Cost reduction (%)**
d. Sample Floor Staircase	28,685.57	27,261.10	1,424.47	4.97%
1.B.2 FINISHING WORK	**84,311.15**	**70,231.56**	**14,079.58**	**16.70%**
1.B.2.1 Plastering				
a. Sample Elevation Column	48,126.78	37,871.68	10,255.09	21.31%
b. Sample Floor Beam	36,184.37	32,359.88	3,824.49	10.57%
1.B.3 PAINTING	**27,874.07**	**23,219.23**	**4,654.84**	**16.70%**
1.B.3.1 Plastic paint				
a. Sample Elevation Column	15,911.17	12,520.74	3,390.43	21.31%
b. Sample Floor Beam	11,962.90	10,698.49	1,264.41	10.57%
TOTAL B……………………	**2,642,664.30**	**2,294,560.84**	**348,103.46**	**13.17%**
TOTAL A+B……………..…	**6,521,978.40**	**5,688,041.80**	**833,936.60**	**12.79%**
15% VAT……..…………..…	**978,296.76**	**853,206.27**	**125,090.49**	**12.79%**
GRAND TOTAL…...……….	**7,500,275.16**	**6,541,248.07**	**959,027.09**	**12.79%**

As clearly shown on table 5.17 the total structural design cost is reduced by 12.79% for structural design using C-40 concrete; similarly as sample structural design for G+2 building; almost all costs for structural design related civil works are reduced for G+7 building. However, cost of reinforced concrete work for staircase and slab is increased by 5.44% (700.17 birr) and 6.18% (25,854.98birr) respectively. In addition to cost of reinforced concrete work, cost of reinforcement work also increased by 7.84% (42,313.84 birr) for slab. On other hand cost of reinforcement and formwork for staircase is reduced by 4.97% (1,424.47 birr) and 1.95% (125.26 birr) respectively. On such design the total cost of slab is increased by 68,168.82 birr whereas the total cost of staircase is reduced by 849.56 birr. Again this shows design of slab using C-40 concrete is not significantly reduced structural design cost rather it increase cost of both reinforced concrete and reinforcement work. However, since the slab thickness is different for both type of designs (i.e structural design using C-25 & C-40 concretes), the slab design may create a little effect on structural design of beams, column and foundations and we may get advantages from design of beam, column and foundation.

Having such indication structural design cost will be more reduced to 13.83% if the slabs is designed using C-25 concrete and considering the effect of slab thickness difference (i.e 15cm thick slab is used for C-40 concrete design and 17cm slab thickness for C-25 concrete design) between the two design on design of beam, column and foundation is negligible.

Thus, again the same as with that of slab design for G+2 building, the design of slab for G+7 building using C-25 concrete is better than design of slab using C-40 concrete unless lesser thickness of slab is used for building designed using C-40 concrete.

5.2.1.3 INTERPRETATION OF STRUCTURAL DESIGN COST FOR G+12 BUILDING

Table 5.18 Interpretation of structural design cost for G+12 building

SUMMARY OF SAMPLE STRUCTURAL DESIGN COST FOR G+12 BUILDING				
Work item description	**Cost with C-25 Concrete**	**Cost with C-40 Concrete**	**Cost reduced**	**Cost reduction (%)**
A. SUBSTRUCTURE WORK				
1.A.1 EXCAVATION & EARTH WORKS	**1,638,378.15**	**1,402,673.37**	**235,704.78**	**14.39%**
1.A.1.1 Pit excavation (0-1.5m depth)	123,286.29	107,996.85	15,289.43	12.40%
1.A.1.2 Pit excavation (1.5-3m depth)	262,518.64	215,391.59	47,127.05	17.95%
1.A.1.3 Backfill around footing	62,887.16	50,444.81	12,442.35	19.79%
1.A.1.4 Backfill around foundation column	765,773.38	672,701.87	93,071.51	12.15%
1.A.1.5 Cart away	423,912.68	356,138.25	67,774.43	15.99%
1.A.2 CONCRETE WORKS	**7,023,102.45**	**5,588,613.82**	**1,434,488.63**	**20.43%**
1.A.2.1 Lean concrete				
a. Under footing	53,182.06	49,305.24	3,876.82	7.29%
b. Under grade beam	8,675.86	7,507.34	1,168.52	13.47%
1.A.2.2 Reinforced concrete				
a. Footing	1,855,786.73	1,640,833.36	214,953.37	11.58%
b. Foundation column	153,724.91	137,706.65	16,018.27	10.42%
c. Grade beam	134,634.88	110,798.89	23,835.99	17.70%
1.A.2.3 Formwork				
a. Footing	141,575.20	112,315.26	29,259.94	20.67%
b. Foundation column	55,592.65	48,292.48	7,300.18	13.13%
c. Grade beam	64,106.54	51,829.53	12,277.01	19.15%
1.A.2.4 Reinforcement work				
a. Footing	2,568,510.78	2,197,398.66	371,112.13	14.45%
b. Foundation column	1,987,312.82	1,232,626.41	754,686.41	37.98%
TOTAL A……………………..……………	**8,661,480.60**	**6,991,287.19**	**1,670,193.41**	**19.28%**
B. SUPER-STRUCTURE				
1.B.1 CONCRETE WORKS	**3,893,297.08**	**2,785,628.07**	**1,107,669.01**	**28.45%**
1.B.1.1 Reinforced Concrete				
a. Sample Elevation Column	304,370.93	273,272.25	31,098.67	10.22%
b. Sample Staircase	13,604.34	13,576.79	27.55	0.20%
c. Sample Floor Beam	91,232.15	64,776.00	26,456.15	29.00%
d. Sample Floor Slab	492,063.49	444,108.94	47,954.55	9.75%
1.B.1.2 Formwork				
a. Sample Elevation Column	109,451.58	96,956.32	12,495.25	11.42%
b. Sample Staircase	6,418.02	6,292.76	125.26	1.95%
c. Sample Floor Beam	60,309.26	53,834.18	6,475.07	10.74%
d. Sample Floor Slab	213,670.60	212,338.27	1,332.33	0.62%
1.B.1.3 Reinforcement work				
a. Sample Elevation Column	1,903,617.11	873,941.88	1,029,675.23	54.09%
b. Sample Floor Beam	142,264.62	137,012.93	5,251.69	3.69%
c. Sample Floor Slab	527,540.55	582,256.64	-54,716.08	-10.37%

SUMMARY OF SAMPLE STRUCTURAL DESIGN COST FOR G+12 BUILDING				
Work item description	**Cost with C-25 Concrete**	**Cost with C-40 Concrete**	**Cost reduced**	**Cost reduction (%)**
d. Sample Floor Staircase	28,685.57	27,261.10	1,493.33	5.19%
1.B.2 FINISHING WORK	**101,825.18**	**88,395.03**	**13,430.15**	**13.19%**
1.B.2.1 Plastering				
a. Sample Elevation Column	63,119.10	56,087.55	7,031.55	11.14%
b. Sample Floor Beam	38,706.08	32,307.47	6,398.61	16.53%
1.B.3 PAINTING	**33,664.38**	**29,224.24**	**4,440.14**	**13.19%**
1.B.3.1 Plastic paint				
a. Sample Elevation Column	20,867.78	18,543.08	2,324.70	11.14%
b. Sample Floor Beam	12,796.60	10,681.16	2,115.44	16.53%
TOTAL B……………………	**4,028,786.63**	**2,903,247.34**	**1,125,539.30**	**27.94%**
TOTAL A+B……………..…	**12,690,267.23**	**9,894,534.53**	**2,795,732.71**	**22.03%**
15% VAT……..…………..…	**1,903,540.08**	**1,484,180.18**	**419,359.91**	**22.03%**
GRAND TOTAL…...………..	**14,593,807.32**	**11,378,714.71**	**3,215,092.61**	**22.03%**

Note 5.1

- Cost reduced = Cost with C-25 Concrete - Cost with C-40 Concrete
- Cost reduced (%) = $\frac{\text{Cost reduced}}{\text{Cost with C−25 Concrete}} x100$

As clearly shown on table 5.18 the total structural design cost is reduced by 22.03% for structural design using C-40 concrete; similarly as sample structural design for G+2 building; almost all costs for structural design related civil works such as civil work for beam, column, foundation and staircase are reduced for G+12 building. However, cost of reinforcement work for slab is increased by 10.37% (54,716.08 birr). On other hand cost of slab for concrete and formwork is reduced by 9.75% (47,954.55 birr) and 0.62% (1,332.33 birr) respectively. On such design the total cost of slab is increased by 6761.53 birr and the total cost of staircase is reduced by 1,646.14 birr. This shows structural design for all elements is reduced except slab due to the usage of concrete grade enhancer admixture.

Having such indication structural design cost for slab is reduced by introducing concrete grade enhancer admixture when the slab is thickness is lower than 15cm.

5.2.2 INTERPRETATION OF OTHER PARAMETERS

This section deals about the effect of concrete grade enhancer admixture on other civil work related parameters such as the amount of cement saved, percentage of floor area reduction which will be occupied by columns and clear height increment due to reduction of beam depth in addition to its effect in related to structural design cost and concrete performance.

5.2.2.1 QUANTITY OF CEMENT

The C-40 concrete can be also achieved by adding more cement without the usage of concrete grade enhancer admixture. However, the quantity of cement without concrete grade enhancer admixture is more for C-40 concrete in compare to the concrete mix with concrete grade enhancer admixture. Accordingly, in this section the amount of cement saved due to the usage of concrete grade enhancer admixture in place of cement is determined.

From practical experience in the construction industry the C-40 concrete grade is achieved by mix ratio of 1:1:2 using volume batching of 50x40x18cm box size. On the hand the C-40 concrete grade also achieved by adding 2% concrete grade enhancer admixture (i.e MegaFlow SP1, High Range Water Reducing Superplasticiser) cement, sand and aggregate mixing proportion of C-25 as clearly proofed using laboratory test on section 5.

Generally, the quantity of cement, sand, aggregate and water for C-40 concrete type with and without concrete grade enhancer admixture including unit rate analysis summary as follow in the table shown below.

Table 5.39 Unit rate analysis for C-40 concrete with admixture

TYPE OF WORK: **CONCRETE WORK** LABOUR HOURLY OUTPUT: 0.75 m^3/hr
WORK ITEM: **1.A.2.2 & 1.B.1.1 Reinforced concrete (Machine mix) - C-40 for column with admixture** EQUIPEMENT: 0.75 m^3/hr
TOTAL QANTITY OF WORK ITEM: 1 m^3 RESULT : **3,806.29 Birr/m^3**

Item .No	Material Cost (1:01)					Labour Cost (1:02)					Equipment Cost (1:03)			
	Type of Material	Unit	Qty	Rate	Cost per Unit	Labour by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
1	Cement	kg	360	2.63	1,183.50	Foreman	1	1/4	50.00	12.50	Hand tools	1	1.00	1.00
2	Sand	m^3	0.42	550	233.46	DL	25	1	15.00	375.00	Mixer	1	85.00	85.00
3	Aggregate	m^3	0.67	560	373.45	Mason	2	1	43.75	87.50	Vibrator	2	25.00	50.00
4	Water	m^3	0.108	7	0.76									
5	Addmixture	Lit	7.2	61	439.20									
		Total (1:01)			2,230.37	**Total (1:02)**				475.00	**Total (1:03)**			136.00

A= Materials Unit Cost 2,230.37 Birr/m^3 B= Manpower Unit Cost 633.33 Birr/m^3 C= Equipment Unit Cost 181.33 Birr/m^3

Total of (1:02) 475 / Hourly Output 0.75 Total of (1:03) 136 / Hourly output: 0.75

Direct Cost of Work Item = A+B+C: 3,045.03 Birr/m^3
Over head cost : 15% 456.76 Birr/m^3
Profit : 10% 304.50 Birr/m^3
Total Unit Cost : 3,806.29 Birr/m^2

Table 5.20 Unit rate analysis for C-40 concrete without admixture

TYPE OF WORK: **CONCRETE WORK** LABOUR HOURLY OUTPUT: 0.75 m^3/hr

WORK ITEM: **1.A.2.2 & 1.B.1.1 Reinforced concrete (Machine mix) - C-40 for column without admixture** EQUIPEMENT: 0.75 m^3/hr

TOTAL QANTITY OF WORK ITEM: 1 m^3 RESULT : **6,799.00 Birr/m^3**

Item .No	**Material Cost (1:01)**					**Labour Cost (1:02)**					**Equipment Cost (1:03)**			
	Type of Material	Unit	Qty	Rate	Cost per Unit	Labour by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
1	Cement (OPC 42.5)	kg	530	3.6	2,385.00	Foreman	1	1/4	50.00	12.50	Hand tools	1	1.00	1.00
2	Sand	m^3	0.39	550	213.87	DL	25	1	15.00	375.00	Mixer	1	85.00	85.00
3	Aggregate	m^3	0.64	560	356.16	Mason	2	1	43.75	87.50	Vibrator	2	25.00	50.00
4	Water	m^3	238.5	7	1,669.50									
		Total (1:01)			4,624.53	**Total (1:02)**				475.00	**Total (1:03)**			136.00

A= Materials Unit Cost 4,624.53 Birr/m^3 B= Manpower Unit Cost 633.33 Birr/m^3 C= Equipment Unit Cost 181.33 Birr/m^3

Total of (1:02) / Hourly Output = 475 / 0.75

Total of (1:03) / Hourly output: = 136 / 0.75

Direct Cost of Work Item = A+B+C: 5,439.20 Birr/m^3

Over head cost : 15% 815.88 Birr/m^3

Profit : 10% 543.92 Birr/m^3

Total Unit Cost : **6,799.00** Birr/m^2

As clearly shown on table 5.19 and 5.20 the quantity of cement for concrete with and without concrete grade enhancer is 360 kg and 530 kg respectively; and the unit rate for concrete work with and without admixture is 3,806.29 and 6799 birr respectively.

Moreover, the percentage of cement saved due to usage of concrete grade enhancer admixture in place of cement summary as follow in the table given below.

Table 5.21 Percentage of Cement Saved

Material	**C-40 Concrete (Without admixture)**	**C-40 concrete (With admixture)**	**Material/Cost Saved**	**Material/Cost Saved (%)**
Cement (Kg)	530	360	**170**	**32.08%**
Sand (Kg)	530	600.8	-70.8	-13.39%
Aggregate (Kg)	1060	1154.2	-94.2	-8.89%
Admixture (Kg)	-	7.2	-7.2	-100%
Water (Lit)	238.5	108	130.5	54.71%
Unit rate	6,799	3,806.29	**2,992.71**	**44.01%**

Thus, the percentage of cement saved due to usage of concrete grade enhancer admixture in place of cement is 32.08% with 44.01% cost reduction for 1m^3 of concrete.

5.2.2.2 FLOOR AREA AND CLEAR HEIGHT

The usage of concrete grade enhancer admixture also have an advantage in related to reduction of floor functional area which will be occupied by columns and it increase the clear height of the building by reducing the requirement of beam depth. Due to the concrete grade is increased from C-25 to C-40 by introducing concrete grade enhancer admixture, the required dimension of beams and columns is less while in compare with structural design with C-25 concrete.

Accordingly, in this section the percentage of area reduction which will be occupied by columns due to the usage of concrete grade enhancer admixture or structural design using C-40 concrete shown as follow in the table given below.

Table 5.22 Colum occupied area reduction

Building Type	Column Type	C-25 Concrete		C-40 Concrete		Reduced Area (m^2)	Reduced Area (%)
		Member	Column occupied Area (m^2)	Member	Column occupied Area (m2)		
G+2	F-1	18	5.652	15	3.5325	-	-
	F-2	12	2.826	15	2.94375		
	Total		8.478		6.47625	**<u>2.00</u>**	**<u>23.61%</u>**
G+7	F-1	12	6.123	6	2.5905	-	-
	F-3	16	7.536	22	8.635		
	F-5	2	0.8635	2	0.7065		
	Total		14.5225		11.932	**<u>2.59</u>**	**<u>17.84%</u>**
G+12	F-1	12	8.007	11	6.47625	-	-
	F-3	16	10.048	17	9.3415		
	F-2	2	1.1775	2	1.0205		
	Total		19.2325		16.83825	**<u>2.39</u>**	**<u>12.45%</u>**

As clearly shown on table 5.22, the minimum column occupied area reduction per floor is 23.61% ($2m^2$), 17.84% ($2.59m^2$) and 12.45% (2.39 m^2) for G+2, G+7 and G+12 buildings respectively. This implies usage of concrete grade enhancer admixture or structural design using C-40 concrete increase the functional area of a certain building by reducing column occupied area especially for huge high rise structures with large number of columns.

Moreover, percentage of increasing floor clear height due to reduction of beam depth for structural design using C-40 concrete (Concrete with concrete grade enhancer admixture) summary in the table given below.

Table 5.23 Floor clear height increment

Building Type	Location	C-25 Concrete		C-40 Concrete		Clear Height Increment (cm)	Clear Height Increment (%)
		Beam Depth (m)	Clear Height (m)	Beam Depth (m)	Clear Height (m)		
G+2	First floor	0.4	2.8	0.35	2.85	5	1.79%
G+7	First floor	0.45	2.75	0.4	2.8	5	1.82%
G+12	First floor	0.5	2.7	0.4	2.8	10	3.70%

Similarly as shown on table 5.23, the minimum floor clear height increment is 1.79% (5cm), 1.82% (5cm) and 3.70% (10cm) for G+2, G+7 and G+12 buildings respectively. Again this shows usage of concrete grade enhancer admixture increase floor clear height by reducing the required depth of especially for multi-story buildings.

Thus, structural design of high rise buildings using C-40 concrete increase the functional area and clear height of floors.

6. CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

It is known that the main aim of the research is investigating the effect of concrete grade enhancer admixture on structural design of high rise building using reinforced concrete in related to concrete performance, structural design cost and other structural design related parameters using laboratory tests and sample structural designs.

As clearly shown on laboratory test result the amount of concrete grade enhancer admixture to be added on a concrete mix of C-25 concrete to get C-40 concrete is 2% of cement by weight. Accordingly, the proportion of cement (PPC), admixture, sand, aggregate and water for C-40 concrete grade is 360 kg, 7.2 kg, 600.8 kg, 1154.2 kg and 108 liter respectively when batching by weight is used. Moreover, the mixing proportion of 1:1:2:3 can be applied when batching by volume is used. Therefore, the required amount of concrete grade enhancer admixture to be added on C-25 concrete mix to get C-40 concrete is 1 liter for one bag of cement or 7.2 liter for $1m^3$ concrete work.

The performance of a plain concrete is measured in terms of its compressive, flexural, and tensile strength. Beside this fact laboratory test is conducted for concrete compressive and flexural strength using 32 cubic and 32 prism concrete specimens with and without the presence of concrete grade enhancer admixture and the tensile strength is determined by empirical formula using compressive strength test result. Accordingly, the 28 days compressive and flexural strength for C-25 concrete for the selected trail mix is 33.35 Mpa and 4.954 Mpa respectively. Whereas the compressive and flexural strength for C-40 concrete is 44.84 Mpa and 7.047 Mpa respectively. This shows the concrete mix with admixture has better performance than a concrete mix without admixture. Moreover, the stress-strain diagram proofs the concrete mix with concrete grade enhancer admixture (C-40 concrete) is more ductile than that of concrete mix without admixture (C-25 concrete).

The total cost structural design and related civil works using C-40 concrete is reduced by 7.74%, 12.79% and 22.03% for G+2, G+7 and G+12 buildings respectively. Among various cost of structural design related civil works cost for beams, columns and footings is highly reduced in compare with slab and staircase; even the structural design cost for slab using C-40 concrete is increased for all buildings. This clearly shows usage of concrete grade enhancer admixture is highly effective in cost reduction for beams, columns and foundation. Moreover, the structural design cost using C-40 concrete is more reduced for high-rise buildings. Thus, structural design cost using C-40 concrete (concrete with concrete grade enhancer admixture) is less in compare with structural design cost using C-25 concrete (concrete without concrete grade enhancer admixture) especially for beams, columns and foundations.

As clearly given on table 6.21 the required amount of cement to get C-40 concrete without the usage of admixture is 530 kg using Ordinary Portland Cement grade type 42.5 N; whereas with concrete grade enhancer admixture is 360 kg with Pazolonic Portland Cement grade type 32.5 N. Furthermore, the average unit price of concrete work for C-40 without admixture is 6799 birr; whereas with admixture is 3,806.29 birr for 1m^3 concrete work. This shows, 170 kg or 32.08% cement and 2992.71 birr or 44.01% concrete work cost is saved due to the usage concrete grade enhancer admixture in place of cement.

The percentage of area reduction which will be occupied by columns due to usage of admixture is 23.61%, 17.84% and 12.45% for G+2, G+7 and G+12 buildings respectively. Whereas the minimum percentage of increasing floor clear height due to reduction of beam depth is 1.79%, 1.82% and 3.70% for G+2, G+7 and G+12 buildings respectively. This shows usage of concrete grade enhancer admixture increase floor functional areas and buildings floor clear height.

Generally beside the fact under this research the following conclusions are made as shown below.

- The amount of concrete grade enhancer admixture to be added on C-25 concrete mix to get C-40 concrete is 2% of cement by weight or 7.2 lit using 360kg PPC cement for 1m^3 concrete work;
- The concrete mix with concrete grade enhancer admixture has better workability, compressive, flexural and tensile strength than concrete mix without admixture;
- The concrete mix with concrete grade enhancer admixture (C-40 concrete) is more ductile than that of concrete mix without admixture (C-25);
- Structural design using C-40 concrete is more effective in cost reduction for beams, columns and footings;
- Structural design cost using C-40 concrete (concrete with concrete grade enhancer admixture) is not significantly reduced unless a lower thickness less than 15cm is used;
- 170 kg or 32.08% cement and 2992.71 birr or 44.01 % concrete work cost is saved due to the usage concrete grade enhancer admixture in place of cement;
- Usage of concrete grade enhancer admixture increase floor functional area and buildings floor clear height.

6.2 RECOMMENDATION

After investigation has been made on "Effect of Concrete Grade Enhancer Admixture on Structural Design of High-Rise Building using Reinforced Concrete at Semera" using laboratory test and sample structural design the following recommendations are given as shown below.

- Use 2% of MegaFlow SP1, High Range Water Reducing Superplasticiser or equivalent concrete grade enhancer admixture by weight of cement (i.e 1 liter for one bag of cement or 7.2 liter for $1m^3$ concrete work) on a mixing proportion of cement, sand and aggregate for C-25 concrete with water cement ratio of 0.3 (i.e 108 liter for $1m^3$ concrete work);
- Use a concrete mix proportion of 1:1:2:3 for C-40 concrete; which is 1 for one bag of cement, 1 for 1 kg of concrete grade enhancer admixture, 2 for two box of sand and 3 for three box of aggregate with a box size of 50x40x18 cm;
- Use C-40 concrete (concrete with concrete grade enhancer admixture) for structural design buildings especially for beams, columns and foundations for moderate to high-rise buildings instead of C-25 concrete;
- Since, getting C-40 concrete without admixture is costly and difficult to attain with our country workmanship quality, use C-40 concrete with concrete grade enhancer admixture for any type of concrete works such as rigid pavements for airfield projects, dams, bridges, ATC towers and the likes in addition to buildings;
- Here, the researcher kindly advice consulting companies and contractors to design reinforced concrete beams, columns and foundations using C-40 (concrete with concrete grade enhancer admixture) instead of C-25 concrete.
- And also, the researcher once again kindly advice bachelor and master's degree students for future investigation of concrete grade enhancer admixture effect on structural design by enhancing the concrete grade from C-15 to C-30 using superplasticiser admixture since C-40 concrete is a high grade concrete and commonly used for pre-stressed concrete not for reinforced concrete;
- Lastly, since the usage of concrete grade highly reduced structural design cost of beams, columns and foundations for all range of building heights, the researcher recommended the Material Engineers and Investors for investigation and creation of concrete grade enhancer admixture using locally available material to reduced cost of admixture which is supplied from foreign companies.

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APPENDIX A - METHOD AND PROCEDURES FOR LABORATORY TEST

A.1 TEST MATERIAL DELIVERY

The materials required for the research are cement, sand, aggregate, concrete grade enhancer admixture and water to prepare 32 rectangular concrete samples for flexural strength test and 32 cubic concrete samples for compressive strength test. Among the total 64 concrete samples 32 of them are casted with concrete grade enhancer admixture to get C-40 concrete. Considering the total number of concrete samples, the quantity of materials required to conduct the test is summarized as shown below.

Table A.1 Quantity of concrete for test samples

Type of test	Concrete Type	Admixture	Specimen Size	No of Specimens	Quantity of Concrete (m^3)
Compressive Strength Test	C-25	Not used	15x15x15 cm	16	0.054
	C-40	Used	15x15x15 cm	16	0.054
Flexural strength test	C-25	Not used	50x10x10 cm	8	0.04
		Not used	60x15x15 cm	4	0.054
		Not used	75x15x15 cm	4	0.0675
	C-40	Used	50x10x10 cm	8	0.04
		Used	60x15x15 cm	4	0.054
		Used	75x15x15 cm	4	0.0675
Quantity of concrete for test samples without admixture(m^3)					0.2155
Quantity of concrete for test samples with admixture(m^3)					0.2155

For C-25 and C-40 concrete types with 1:2:3 and 1:1:2:3 mixing ratio by volume respectively, the amount of cement, sand, aggregate and admixture for all test samples computed as follow shown below;

Cement = 450 kg*(0.2155+0.2155) = 193.95 kg = 193.95 kg/50kg/Bag = 3.88 bags **= <u>4 bags</u>**

Sand = 4*2*0.4*0.5*0.18 = 0.288 m^3 = 0.288 m^3*1850kg/m^3 = **<u>532.8 kg</u>**

Aggregate = 4*3*0.4*0.5*0.18 = 0.432 m^3 **=** 0.432 m^3*2250 kg/m^3 = **<u>972 kg</u>**

Admixture = 4*2/2 = **<u>4 Liter or 4 kg</u>** (Assuming 2 Liter per 100kg or 2% by weight of cement)

Thus, by adding material wastage and probable changes during test, the quantity of materials delivered at Addis Ababa Science and Technology University Structural Laboratory are;

- Cement = 300 kg **= <u>6 bags</u>**
- Sand = 15 box = 15*0.036 = 0.54 m^3 = 0.54 m^3*1850kg/m^3 = **<u>999 kg</u>**
- Aggregate = 20 box = 20*0.036 = 0.72m^3= 0.72 m^3*2250 kg/m^3 = **<u>1620 kg</u>**
- Admixture = **<u>5 Liter</u>**

Figure A.1 Loading of materials for laboratory tests

Unloading of aggregate

Unloading of admixture

Unloading of Sand

Unloading of Cement

Figure A.2 Unloading of materials for laboratory tests

A.2 TEST METHOD

The tests required for the investigation of concrete grade enhancer admixture on structural design of high rise building using reinforced concrete are compressive and flexural strength tests. For conducting such a tests there are four 50x10x10cm, two 60x15x15cm and two 75x15x15cm rectangular molds for flexural strength test with eight 15x15x15cm cubic molds for compressive strength test at Addis Ababa Science and Technology University. Having such number of molds the concrete samples casting takes four days to cast the required 60 concrete samples for the research.

Generally the laboratory test follows the following major steps;

Step 1 - Fixing test mold

Step 2 - Oiling test mold

Step 3 - Material batching

Step 4 - Concrete mixing

Step 5 - Check workability of concrete mix using slump test

Step 6 - Concrete casting and Vibrating

Step 7 - Cleaning laboratory equipment and demolishing test mold

Step 8 - Curing of concrete

Step 9 - Conducting laboratory test

Step 9.1 - Conducting compressive strength test

Step 9.2 - Conducting flexural strength test

A.2.1 FIXING TEST MOLD

The test molds used to conduct both flexural and compressive strength tests are made of interconnected rectangular metal plates through bolt and nuts. The rectangular plates are connected to each other to form prism or cubic by using a bolt of 17mm diameter with a nut of 19mm external diameter. The bolts and nuts are squeezed and tightened using a hand tools called “Stela and “Engliz cabe or drop forged” with hand hammer by rotating the bolts in anticlockwise direction.

Figure A.3 Fixing of test molds

A.2.2 OILING TEST MOLD

The test molds are oiling with burnt oil from a waste of machine motors or vehicle oil to prevent the sticky of the concrete with the test molds while demolishing the concrete mold after 24 hours for reuse of the mold for casting other concrete test samples using oil brush. The primary and foremost use of the oil is just to keep the mold and the casted concrete samples unstick during demobilizing of molds and makes the demolishing work easy.

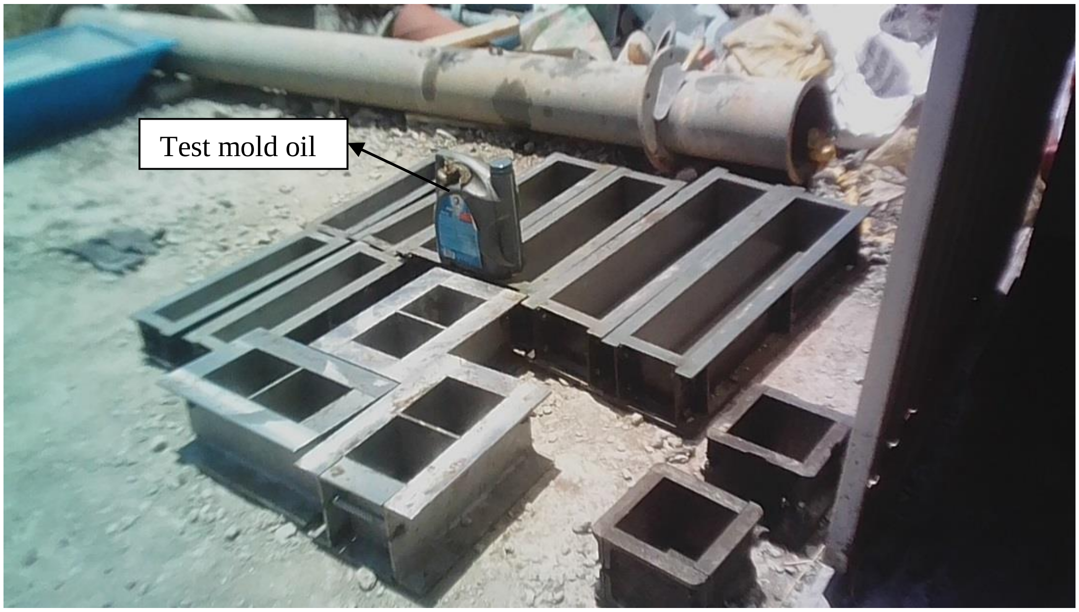


Figure A.4 Oiling test molds

A.2.3 MATERIAL BATCHING

The materials used for concrete mix can be batched using either volume or weight depending on the availability of batching equipment's. Among the two possible way of batching, this research uses batching by weight; since the available type of concrete batching at Addis Ababa Science and Technology University is batching by weigh using electrical balance. The balance plugged to electric source through its socket and measured the weight of materials in kilogram.

All the materials, cement, sand, aggregate, concrete grade enhancer admixture and water used for concrete mix are batched by weight. The weight of the material calculated on the basis of concrete grade and the mixer mixing capacity at a time. The capacity of the mixer to mix at a time is 90 liter or 0.09 m^3. The available test molds that can be casted per days are eight flexural and eight compressive strength test molds.

On such instant the concrete volume of all the 16 samples can be computer as follow shown in the table below.

Table A.2 Concrete volume casted per day

Type of molds	Compressive Strength Test	Flexural strength test		
Size of Molds	15x15x15 cm	50x10x10 cm	60x15x15 cm	75x15x15 cm
No Molds	8	4	2	2
Quantity of Concrete (m^3)	0.027	0.02	0.027	0.03375
Total Concrete Volume (m^3)				**0.10775**

Having 0.10775 m^3 or 107.75 liter of concrete that can be casted per day with available of 16 test molds, the minimum number of mix per day with a mixer capacity of 90 liters is two. Thus, the quantity of materials to mix 0.10775 m^3 of concrete in two rounds is computed as follow shown below.

Trial batching for C-25 concrete weighted on March 07, 2018

(360 kg of cement, 600.8 kg of Sand, 1154.2 kg of aggregate & 200 liter of water for 1m^3 concrete work)

Round 1 & 2 Mix

- Cement = 360kg/m^3*0.10775m^3/2 = **19.4 kg**
- Sand = 600.8kg/m^3*0.10775m^3/2 = **32.37 kg**
- Aggregate = 1154.2kg/m^3*0.10775m^3/2 = **62.18 kg**
- Water = 200liter/m^3*0.10775m^3/2 = 10.78 liter = **10.78 kg**

Round 3/Additional Mix

Due to the above two round mixes are not adequate to cast all the 16 test samples because of some concrete wastage, additional mix is required to cast the remaining three 50x10x10cm sized flexural strength mold.

- Quantity of concrete = 3*0.5*0.1*0.1m^3 = **0.015 m^3**
- Cement = 360kg/m^3*0.015m^3 = **5.4 kg**
- Sand = 600.8kg/m^3*0.015m^3 = **9.01 kg**
- Aggregate = 1154.2kg/m^3*0.015m^3 = **17.3 kg**
- Water = 200liter/m^3*0.015m^3 = 3 liter = **3 kg**

Trial batching for C-40 concrete weighted on March 08, 2018

(360 kg of cement, 600.8 kg of Sand, 1154.2 kg of aggregate, 2% admixture by weight of cement & w/c = 0.3 for 1m^3 concrete)

Round 1 & 2 Mix

- Quantity of concrete = 0.10775m^3 +0.015m^3 **= 0.12275 m^3**
- Cement = 360kg/m^3*0.12275m^3/2 = **22.1 kg**
- Sand = 600.8kg/m^3*0.12275m^3/2 = **36.87 kg**

- Aggregate = 1154.2kg/m^3*0.12275m^3/2 = **70.84 kg**
- Admixture = 0.02*22.1kg = **0.44 kg**
- Water =0.3*22.1kg= 6.63 = **6.63 kg**

Round 3/Additional Mix

Due to the above two round mixes are not adequate to cast all the 16 test samples because of some concrete wastage and water is reduced due to addition of admixture, additional mix is required to cast the remaining one 75x15x15cm sized flexural strength mold and one 15x15x15cm sized compressive strength mold.

- Quantity of concrete = (1*0.75*0.15*0.15 +1*0.75*0.15*0.15) m^3 = **0.02025 m^3**
- Cement = 360kg/m^3*0.02025m^3 = **7.29 kg**
- Sand = 600.8kg/m^3*0.02m^3 = **12.17 kg**
- Aggregate = 1154.2kg/m^3*0.02m^3 = **23.3 kg**
- Admixture = 0.02*7.29kg = **0.15 kg**
- Water =0.3*7.29kg = **2 kg**

Trial batching for C-25 concrete weighted on March 09, 2018

(450 kg of cement, 643.16 kg of Sand, 1146.4 kg of aggregate & 195 liter of water for 1m^3 concrete)

Round 1 & 2 Mix

- Cement = 450kg/m^3*0.10775m^3/2 = **24.24 kg**
- Sand = 643.16kg/m^3*0.10775m^3/2 = **34.65 kg**
- Aggregate = 1146.4kg/m^3*0.10775m^3/2 = **61.76 kg**
- Water = 195liter/m^3*0.10775m^3/2 = 10.51 liter = **10.51 kg**

Round 3/Additional Mix

Due to the above two round mixes are not adequate to cast all the 16 test samples because of some concrete wastage, additional mix is required to cast the remaining two 50x10x10cm sized flexural strength mold.

- Quantity of concrete = 2*0.5*0.1*0.1m^3 = **0.01 m^3**
- Cement = 450kg/m^3*0.01m^3 = **4.5 kg**
- Sand = 643.16kg/m^3*0.01m^3 = **6.43 kg**
- Aggregate = 1146.4kg/m^3*0.01m^3 = **11.46 kg**
- Water = 195liter/m^3*0.01m^3 = 1.95 liter = **1.95 kg**

Trial batching for C-40 concrete on March 10, 2018

(450 kg of cement, 643.16 kg of Sand, 1146.4 kg of aggregate, 1.5% admixture by weight of cement & w/c = 0.3 for 1m^3 concrete)

Round 1 & 2 Mix

- Cement = 450kg/m^3*0.10775m^3/2 = **24.24 kg**
- Sand = 643.16kg/m^3*0.10775m^3/2 = **34.65 kg**
- Aggregate = 1146.4kg/m^3*0.10775m^3/2 = **61.76 kg**
- Admixture = 0.015*24.24kg = **0.36 kg**
- Water =0.3*24.24kg/m^3= **7.27 kg**

Round 3/Additional Mix

Due to the above two round mixes are not adequate to cast all the 16 test samples because of some concrete wastage and water is reduced due to addition of admixture, additional mix is required to cast the remaining four 15x15x15cm sized compressive strength mold.

- Quantity of concrete = 4*0.15*0.15*0.15m^3 = **0.0235 m^3**
- Cement = 460kg/m^3*0.0135m^3 = **6.08 kg**
- Sand = 643.16kg/m^3*0.0135m^3 = **8.68 kg**
- Aggregate = 1146.4kg/m^3*0.0135m^3 = **15.48 kg**
- Admixture = 0.015*6.075kg = **0.09 kg**
- Water =0.3*6.075kg/m^3= 2 liter = **1.82 kg**

Water weighting

Aggregate weighting

Sand weighting

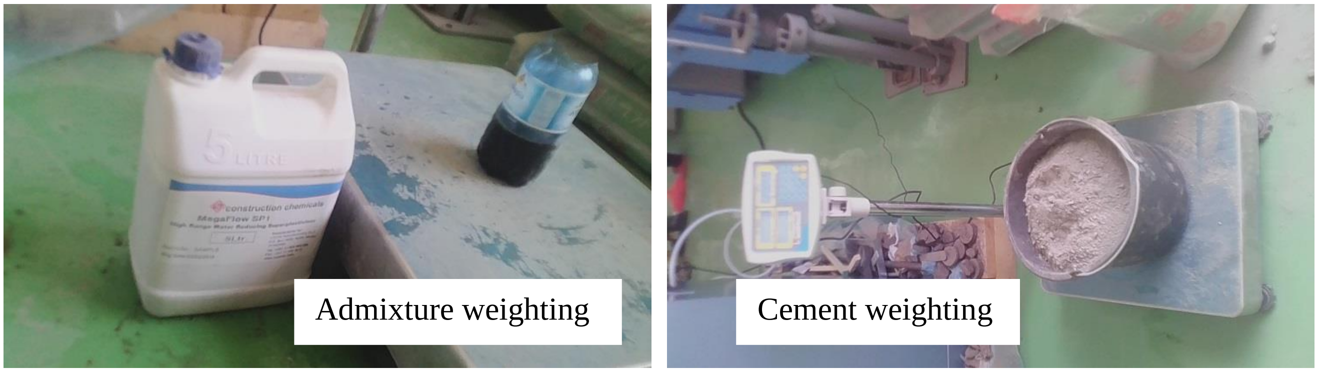


Figure A.5 Material batching

A.2.4 CONCRETE MIXING

The concrete mix is done for four days with four different concrete trial mixes. The first day concrete mix is prepared using 360 kg cement, 600.8 kg Sand, 1154.2 kg aggregate & 200 liter water on March 07, 2018 for C-25 concrete; the second day with 360 kg cement, 600.8 kg Sand, 1154.2 kg aggregate, 2% admixture by weight of cement & w/c of 0.3 on March 08, 2018 for C-40 concrete; the third day with 450 kg cement, 643.16 kg Sand, 1146.4 kg aggregate & 195 liter water on March 09, 2018 for C-25 concrete and the last day concrete mix is prepared using 450 kg cement, 643.16 kg Sand, 1146.4 kg aggregate, 1.5% admixture by weight of cement & w/c = 0.3 on March 10, 2018 for C-40 concrete to cast $1m^3$ of concrete work.

The trial concrete mix is prepared based on reviewing previous works and experience on the construction industry. From a review of more than 35 laboratory tests results conducted for compressive strength of concrete, the amount of cement for C-25 concrete ranges from 360-400 kg for $1m^3$ concrete work with Ordinary Portland Cement. Whereas, with that of Pozolana Portland cement, the amount of cement for $1m^3$ concrete work ranges from 400-450kg to get C-25 concrete. The amount of concrete grade enhancer admixture added on a mix proportion of cement, sand, aggregate of C-25 concrete to get C-40 concrete is decided based on admixture supplier specification recommendation and experience on pervious works.

The concrete grade enhancer admixture, MegaFlow SP1 is a highly effective water reducing superplasticiser and an extremely powerful de-flocculating agent based on soluble salt of polymericnapthalene sulphonate. It is used to produce a flowing concrete for the congested areas, slabs, foundations, large pours, beams, columns and precast elements. It provides excellent strength gain at early ages and major increase at all ages of concrete. The recommended dosage is 0.5 - 3.0% by weight of cementitious material. The optimum dosage of MegaFlow SP1 and its effect on concrete properties such as workability, strength, setting time, etc. are best assessed after conducting laboratory tests using the mixing proportion of C-25 concrete to get C-40 concrete.

The concrete is mixed using mechanical mixer called drum type of mixer with a mixing capacity of 90 liters. The mixer is worked with electrical source by plugging its socket to electric source. The ingredients mixing thoroughly using the mixer up to 5-10 minutes. The duration of mixing is decided by visual observation during mixing inside the mixer.

Generally the concrete mixing follows the following procedures to mix the concrete required to cast half of 0.10775 m^3 at a time.

Step 1 - Add of water

Step 2 - Add concrete grade enhancer admixture (for C-40 Concrete)

Step 3 - Add aggregate (First round)

Step 4 - Add sand

Step 5 - Add aggregate (Second round)

Step 6 - Add cement

Step 7 - Mix the concrete

Step 8 - Pour concrete mix

Note A.1 Since the amount of aggregate is more in the concrete mix, it adds on mixer in two rounds for thoroughly mix of concrete ingredients.

Figure A.6 Concrete Mixing

A.2.5 CONCRETE CASTING AND VIBRATING

The concrete is casted on fixed, cleaned and oiled test molds using different hand tools such as concrete spoon or trowel, shovel, tamping rod, plastic pan. The concrete fill in the molds in layers approximately 5cm thick and concrete sample casting and vibrate or tamping at three layers using a steel tamping road. The concrete should compact or vibrate not less than 35 strokes per layer and the top surface should be level and smoothen it with a trowel.

Figure A.7 Concrete casting and vibrating

Generally the test concrete casting follows the following procedures;

Step 1 - Clean the mounds and apply oil

Step 2 - Fill the concrete in the molds in layers approximately 5cm thick

Step 3 - Compact each layer with not less than 35strokes per layer using a tamping rod (steel bar 16mm diameter and 60cm long, bullet pointed at lower end)

Step 4 - Level the top surface and smoothen it with a trowel

A.2.6 CLEANING LABORATORY EQUIPMENT AND DEMOLISHING TEST MOLD

The laboratory test uses a lot of equipment's such as tamping rod, sump cone, plastic pans, electronic balance, concrete mixer, trowel, shovel, universal testing machine and the like to cast, cure and crashed test samples. The equipment's and the laboratory room cleaned to avoid dirties and debris during laboratory works by washing and sweeping.

The laboratory has only 16 test molds however the number of samples required to investigate the effect of concrete grade enhancer admixture on structural design of high rise building are 60; because of this reuse of the mold is necessary to prepare all the required number of concrete samples. Moreover, in order to cure the concrete samples by socking with water in socking tanker, the mold should be demolished. The test molds demolished using hand tools called Stela and Engliz cabe or drop forged with hand hammer by rotating the bolts in clockwise direction after 24 hours or after hardening of concrete.

Figure A.8 Cleaning laboratory equipment's and demolishing test molds

A.2.7 CURING OF CONCRETE

The concrete curing process involves a reaction between cement and water helping on releasing heat from the concrete at a desired and controlled rate. Without curing, moisture is lost too quickly and there is not enough water necessary for the crystals to grow, resulting in weaker concrete strength. Concrete can be cured using either water or plastic members. Water curing also done using a techniques called immersion, ponding, fogging, and wet covering. Among different techniques of concrete curing this test uses concrete curing by water by immersing the casted test samples for a minimum of seven days after demolishing of the concrete molds.

The casted concrete test specimen also removed from water after seven days curing time and wipe out excess water from the surface to conduct flexural and compressive strength tests. All the casted 64 concrete specimens was removed from the socked plastic tanker or pan at the seventh age of concrete and 32 of them prepares for laboratory test and the remaining 32 concrete specimens put for 28th day concrete test.

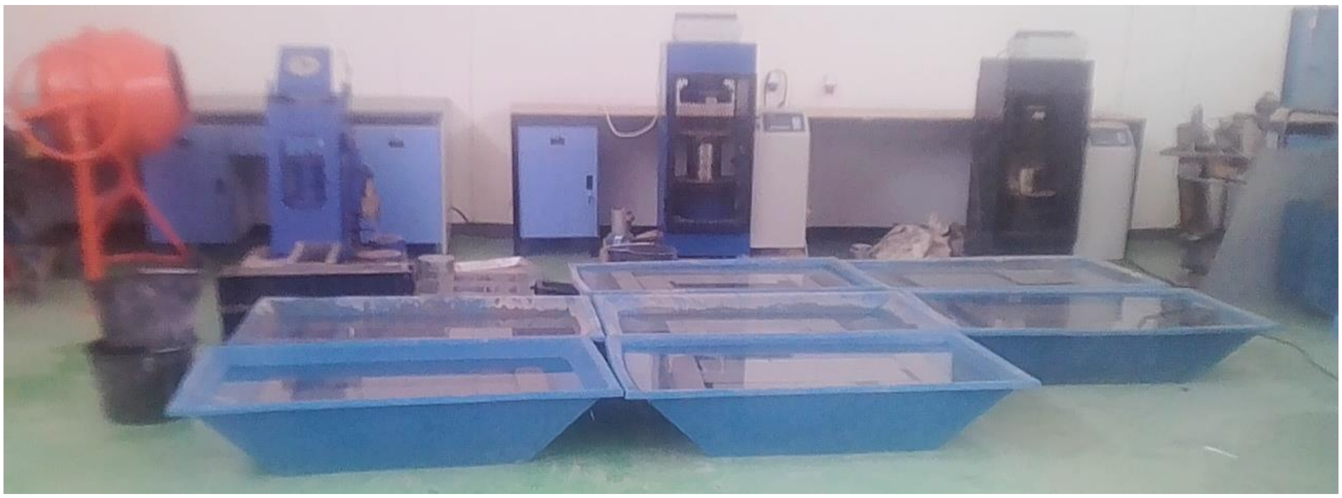


Figure A.9 Concrete curing

Figure A.10 Concrete removing from water

A.3 TEST PROCEDURE

The laboratory test is done for concrete flexural and compressive strength tests. The tests are conducted using F 060 Universal Testing Machine. The machine generally used to conduct tensile tests on round or flat metal bars, compression tests on metal cylinders with flat and parallel faces, compression tests on cubes or cylinders of concrete, cement, masonry etc, flexure tests on profiles or beams of various materials and bending tests on metal profiles with a digital control using computerized program. The computer installed with Tecnotest software to run the execution of the required laboratory test.

The software give different outputs depending on the interest of the user selection such as test value like maximum load, tensile strength, flexural strength, compression strength, test details, graphs like load-time, deformation-time, load-deformation, stress-strain with printed paper or in PDF formats.

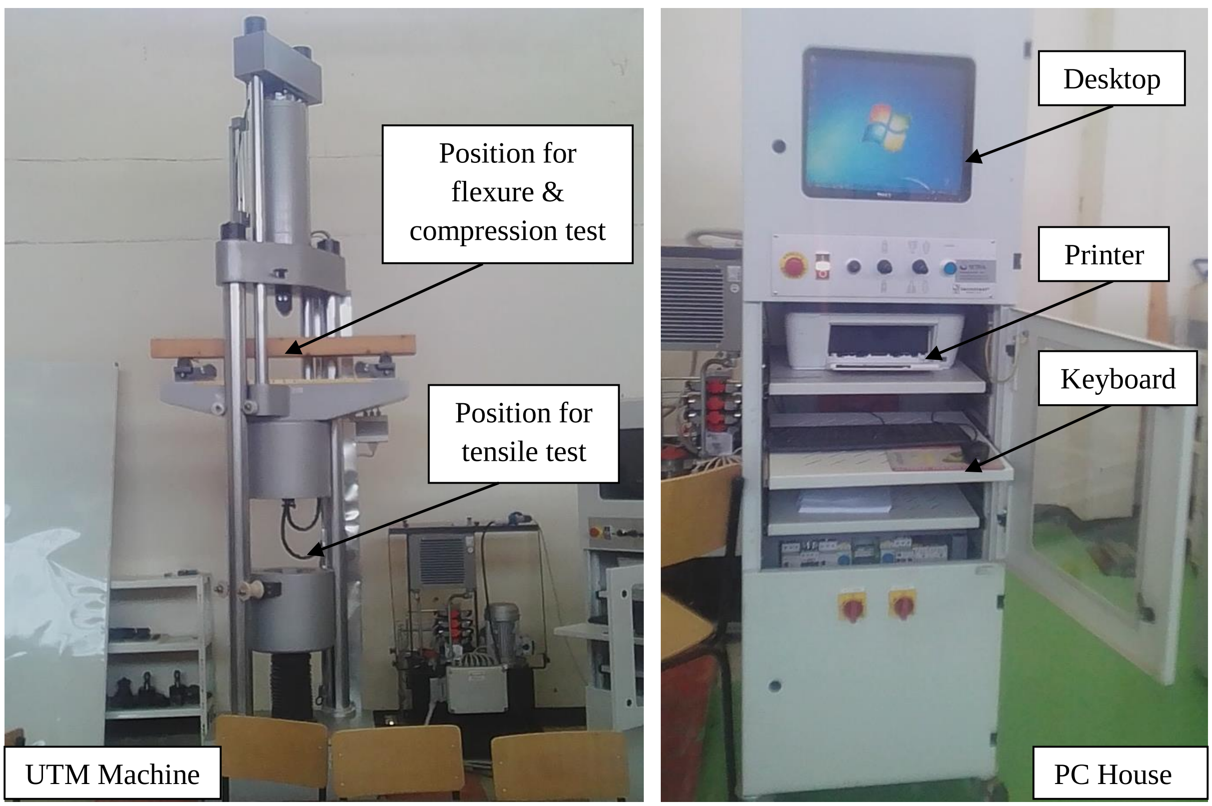


Figure A.11 F 060 Universal Testing Machine

A.3.1 FLEXURAL STRENGTH TEST PROCEDURE

The flexural strength test is conducted to know the flexural strength or modulus of rupture or bend strength of beam. The test is employed, in which a specimen having rectangular cross-section is bent until fracture or yielding using one, two or three point loading techniques. The choice of flexural strength test types depends on various factors such as span length of specimen, availability of equipment's. For this research one point flexural strength test is used because of the available digital type of computer controlled machine called F 060 Universal Testing Machine has one point loading. Moreover the available machine is one point flexural testing machine, conducting one point flexural strength test is better to get the maximum effect on small span concrete specimens than that of two point flexural strength test.

Generally the activity of conducting one point flexural strength test follows the steps given below.

<u>Step 1</u> - Plugged the power socket

The testing machine has two sockets that must be plugged to conduct any type of tests; one socket supply power for computer accessories such as desktop, printer, monitor and the second one for supplying electric power for all the machine parts like motor, hydraulic jack.

Figure A.12 Power Socket for UTM

<u>Step 2</u> - Power on the machine

The power of the machine is switch on by rotating the red mushroom or emergency button in the direct ion of the arrow and pressing the green push button.

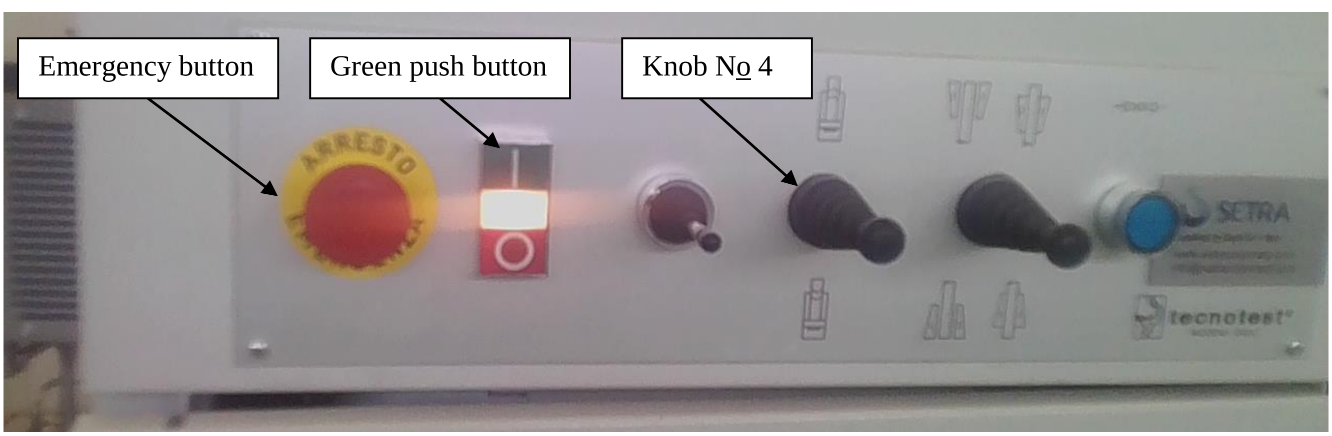


Figure A.13 Machine power on buttons

Step 3 - Fill the firm address

The client or the owner of the machine address is filled by:

Step 3.1 - Click one time on Tecnotest icon from desktop then press shift key

Step 3.2 - Keeping pressing shift key and press enter until access table appeared

Step 3.3 - Click on "tim bro ditta" and write name & address of the company and close the window

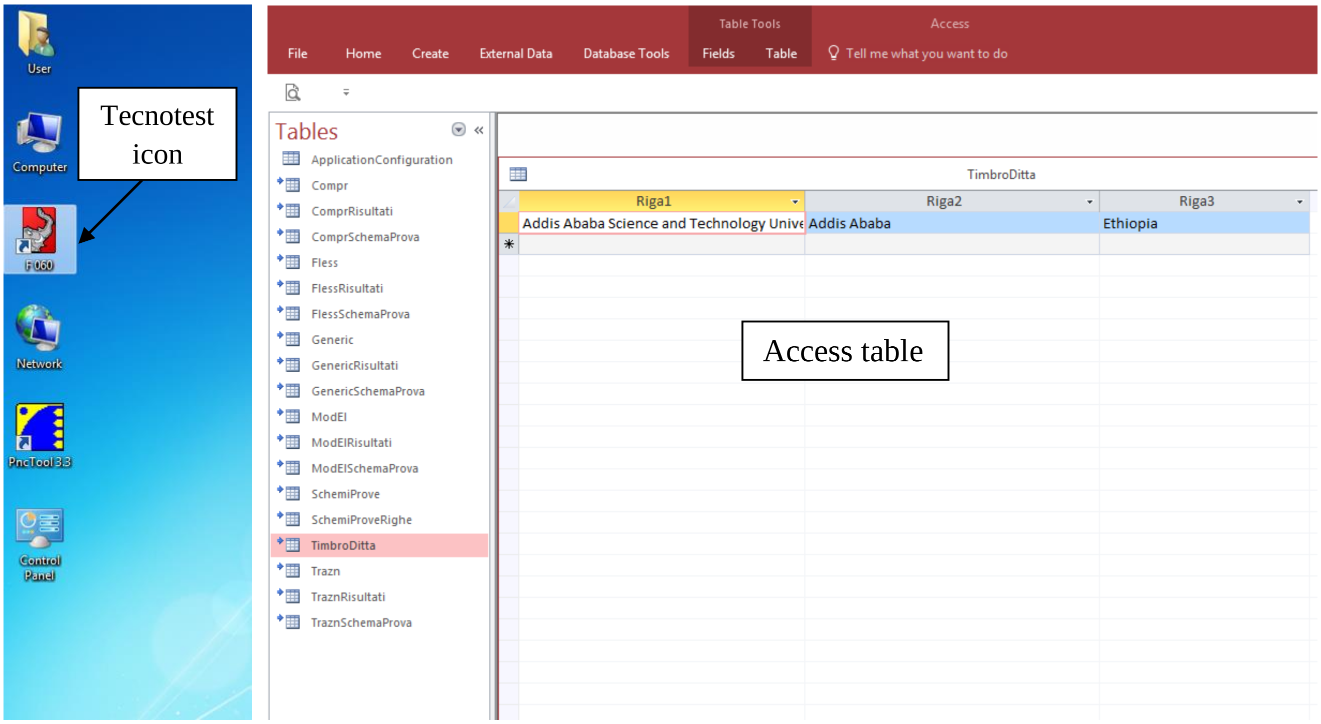


Figure A.14 Filling firm address

Step 4 - Preparation of the machine for flexure test

The testing machine prepared for flexural strength test as follows:

Step 4.1 - Insert the central bearer in its seat on the underside of cross-beam using knob situated on the front of the cross-beam to clamp or release the machine.

Step 4.2 - Place the lower supports at the required span by loosen the blocking bolts using No 28 Stela or drop forged by rotation in clockwise direction; the span of the support adjusted for 50cm, 60cm and 75cm to conduct 50x10x10cm, 60x15x15cm and 75x15x15cm rectangular specimens respectively.

Step 4.3 - Block the support bearers using the blocking bolts using No 28 Stela or drop forged by rotation in anticlockwise direction.

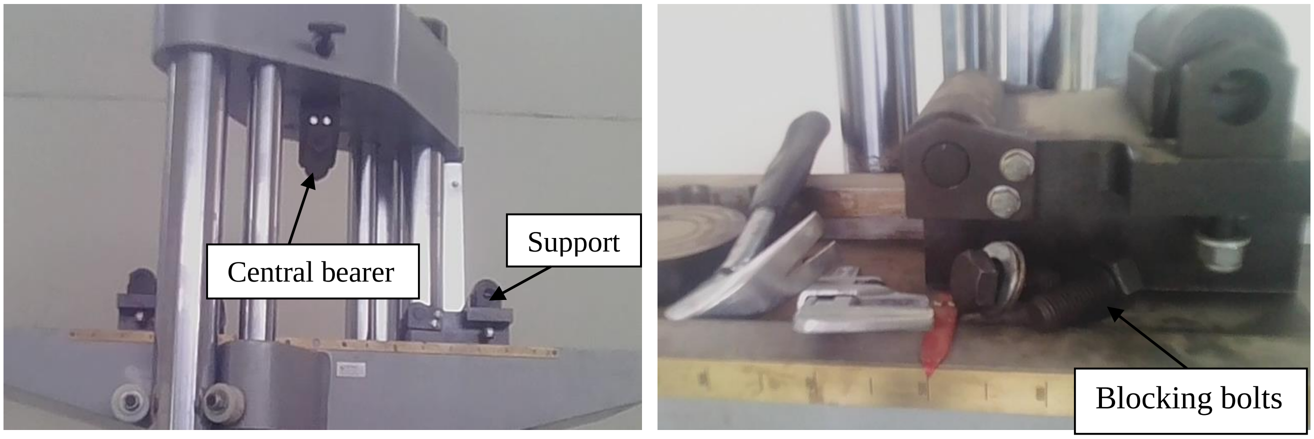


Figure A.15 Preparation of machine for flexure test

<u>Step 5</u> - Preparation of the sample for flexural strength test

The sample is placed on at center of the support and move in the required direction using knob No 4. The knob number 4 in figure 3.14, activates the main hydraulic ram; in the 12 o'clock position the upper gripping head rises and in the 6 o'clock position it descends.

<u>Note A.2</u> If there is a risk that the sample will fail in a non-symmetrical manner, it is recommended to limit oscillations of one or both of the lower supports by tightening the nuts that hold the pin support ears. The sample should be carefully centered on the supports.

<u>Note 3.3</u> Before starting the test it is recommended that the daylight between the sample and the upper bearer is reduced. However, care should be taking while upping the machine to reduce the daylight between the sample and the bearer to avoid breaking of the sample before run the test.

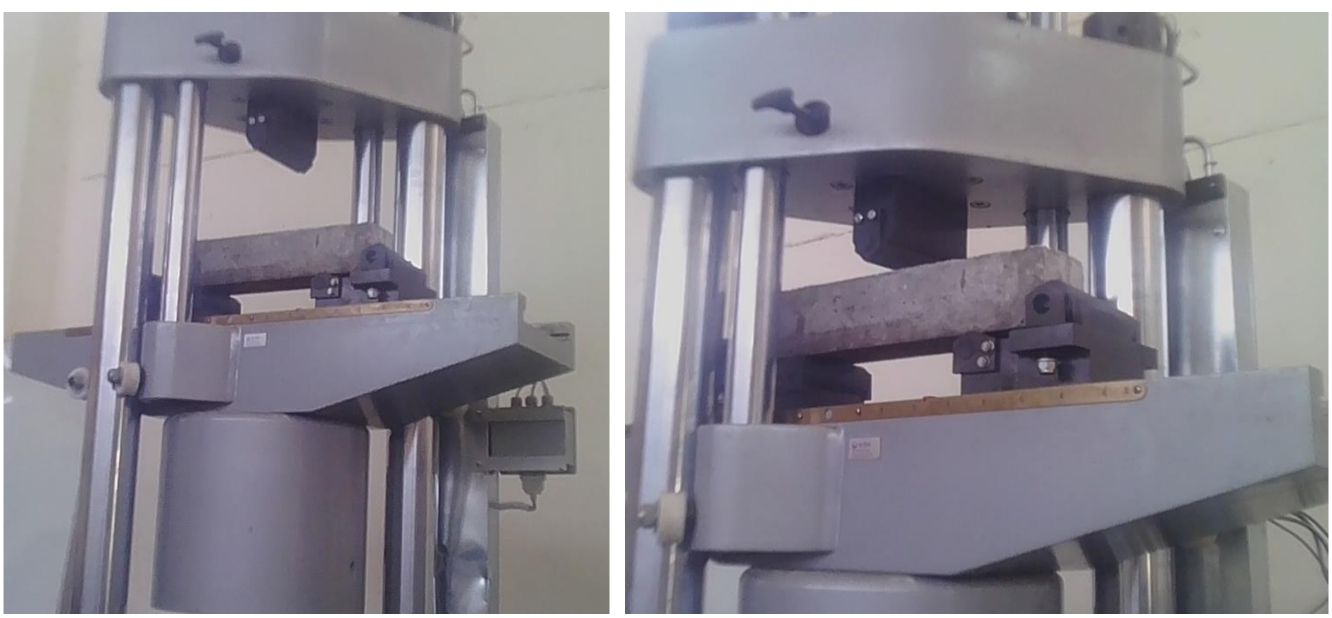


Figure A.16 Preparation of the sample for flexural strength test

<u>Step 6</u> - Conduct flexural strength test

The flexural strength test conducted as follows:

<u>Step 6.1</u> - Click on Tecnotest icon on desktop to start the test;

<u>Step 6.2</u> - Select type of test from dropdown list as “Flexural Test” and click “Ok” icon;

<u>Step 6.3</u> - Enter first level password as “123” and second level as “456” to allow use of test management;

<u>Step 6.4</u> - Select test management and click “Yes” to continue conducting new test;

<u>Step 6.5</u> - Fill input data by clicking on “Modify” icon;

<u>Step 6.6</u> - Click on “START” icon and then click on “CYCLE START” to run the test;

<u>Step 6.7</u> - Save the test result in database by clicking “Ok” icon while the “Test result saved in DataBase” message box appeared immediately at the end of the test;

<u>Step 6.8</u> - Read or print or snip the test results; the test result may be maximum load, maximum flexural strength, test details and different graphs. To get the graph click on “Graph” icon then choose the type of graphs by clicking “Load Graph”, Deformation Graph”, Load-Deformation Graph” and “Stress-Strain Graph”.

<u>Note A.4</u> The test is finished when one of the following conditions is met when fragile failure of the sample or arrival at the pre-set load limit or pre-set deformation limit or by pressing key “STOP". Among the above possible condition to end the test, this test finished while the sample is break or fragile failure of the sample is occurred.

<u>Note A.5</u> In the box “Test Number” the system always proposes the last test executed (the program automatically assigns tests with a progressive number, without the option for modifications); press the left arrow key (next to FIND) to go to the previous test; or the right arrow key to move to the next. If the user knows the specific test number, press FIND and enter the number in the drop-down menu displayed.

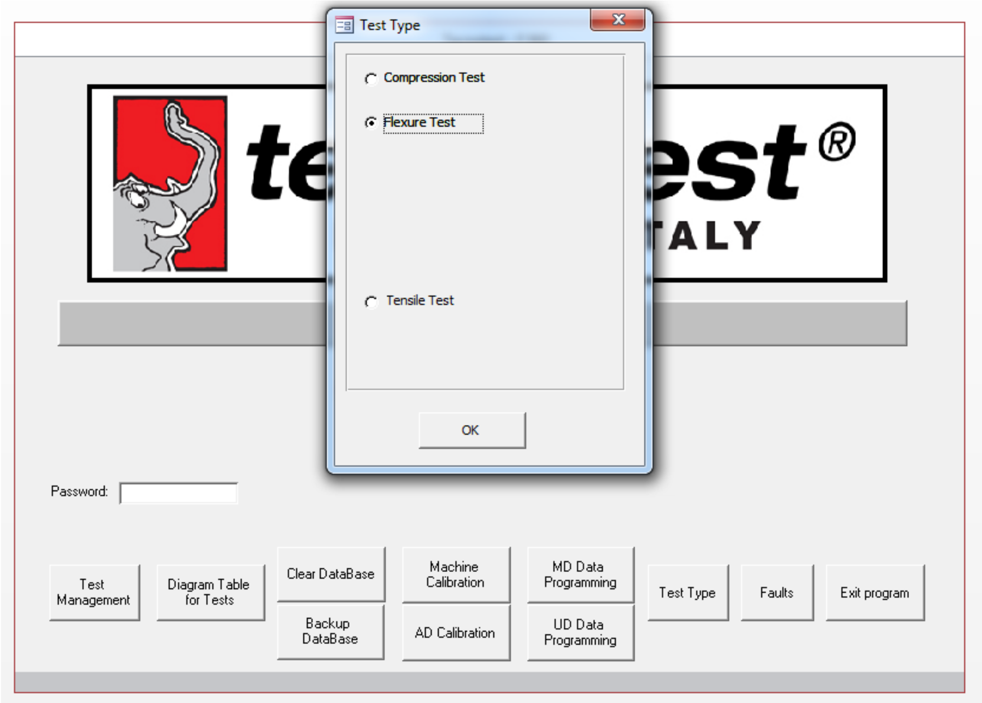


Figure A.17 Selecting test type

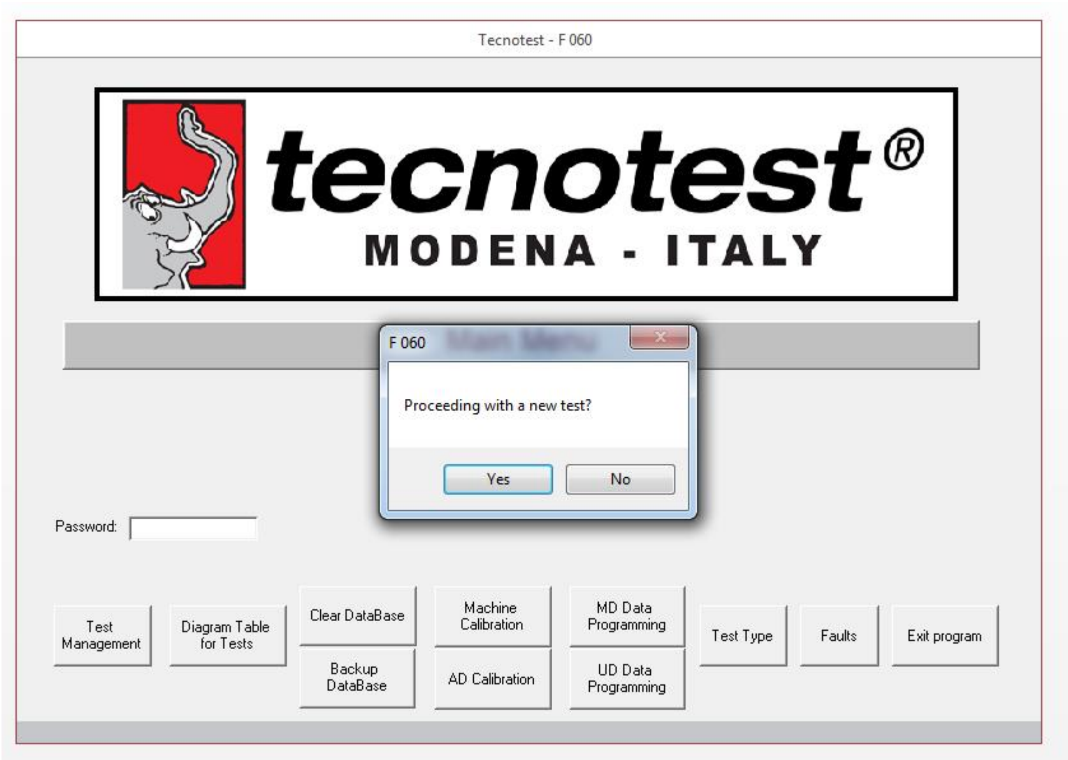


Figure A.18 Selecting test management

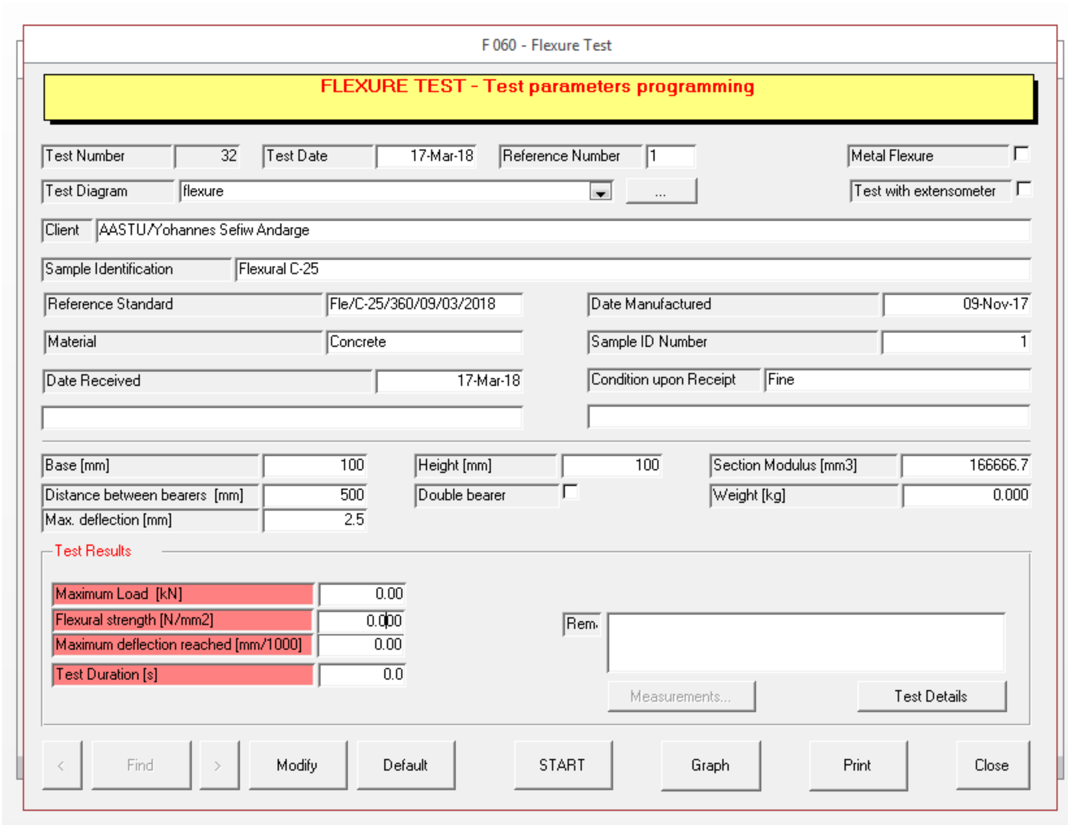


Figure A.19 Filing input data for flexure test

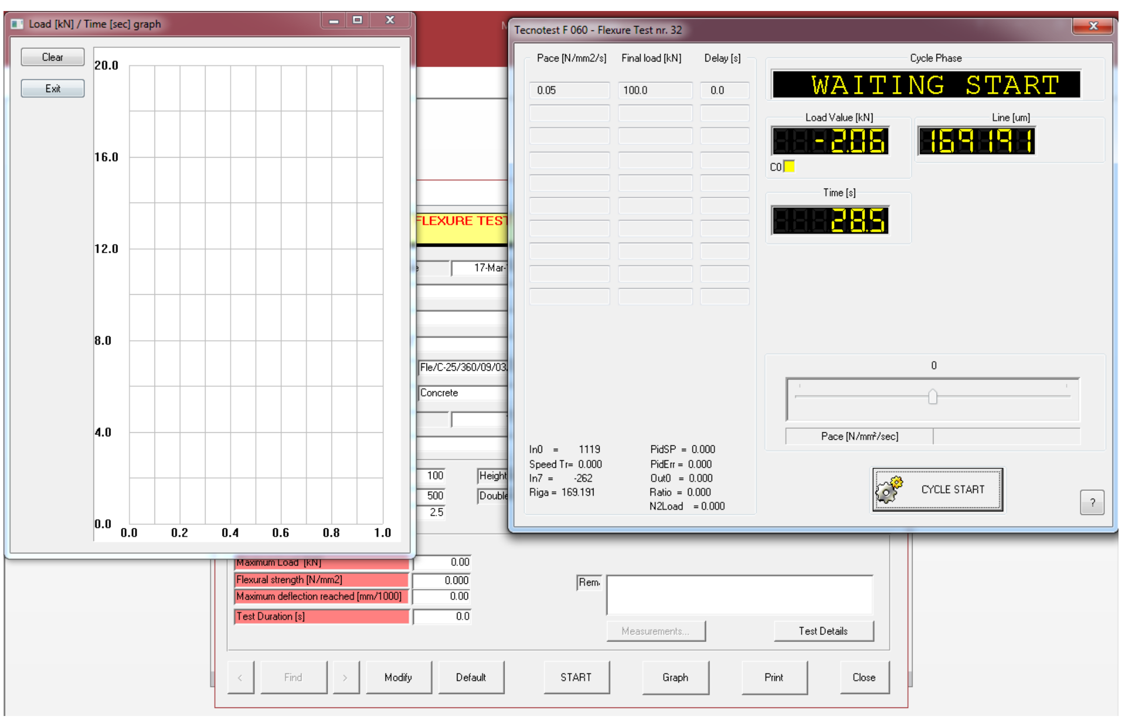


Figure A.20 Starting flexural test

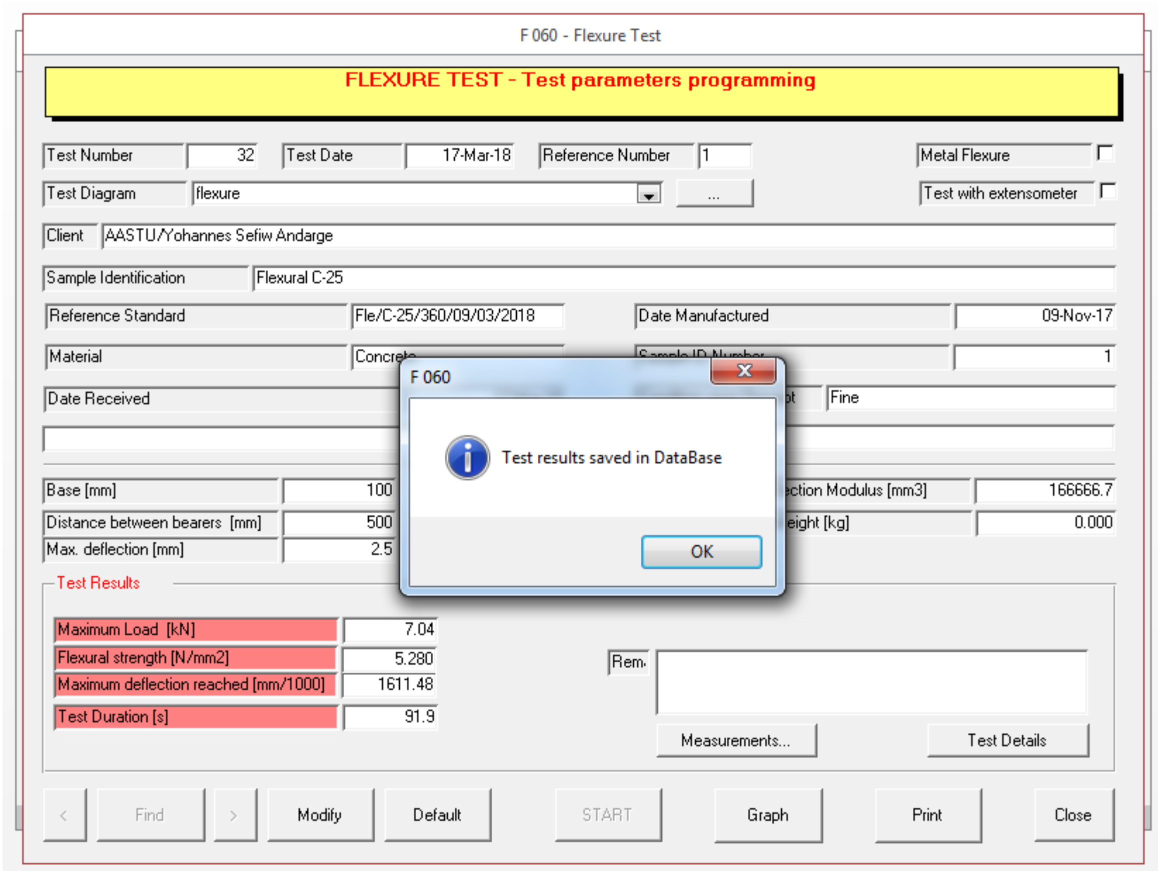


Figure A.21 Test result saving in DataBase for flexure test

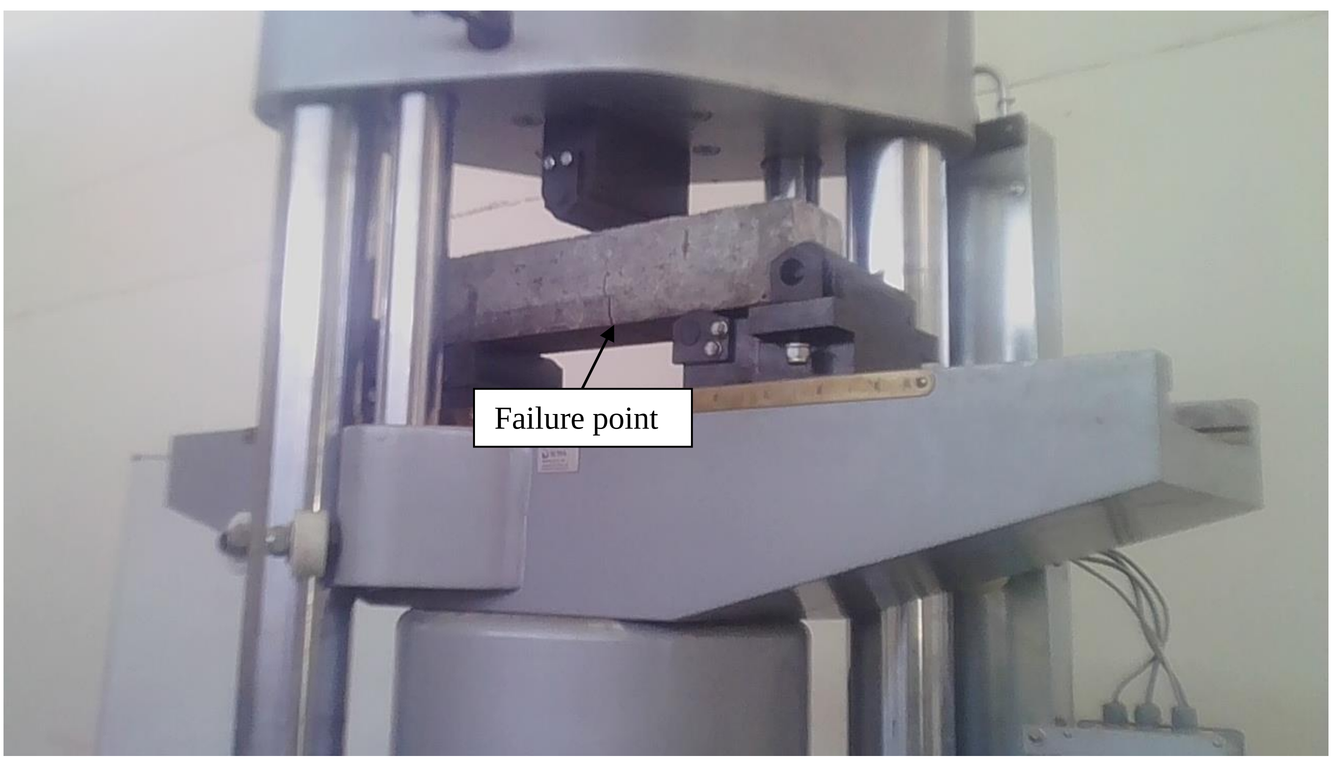


Figure A.22 Fragile failure of the sample for flexure test

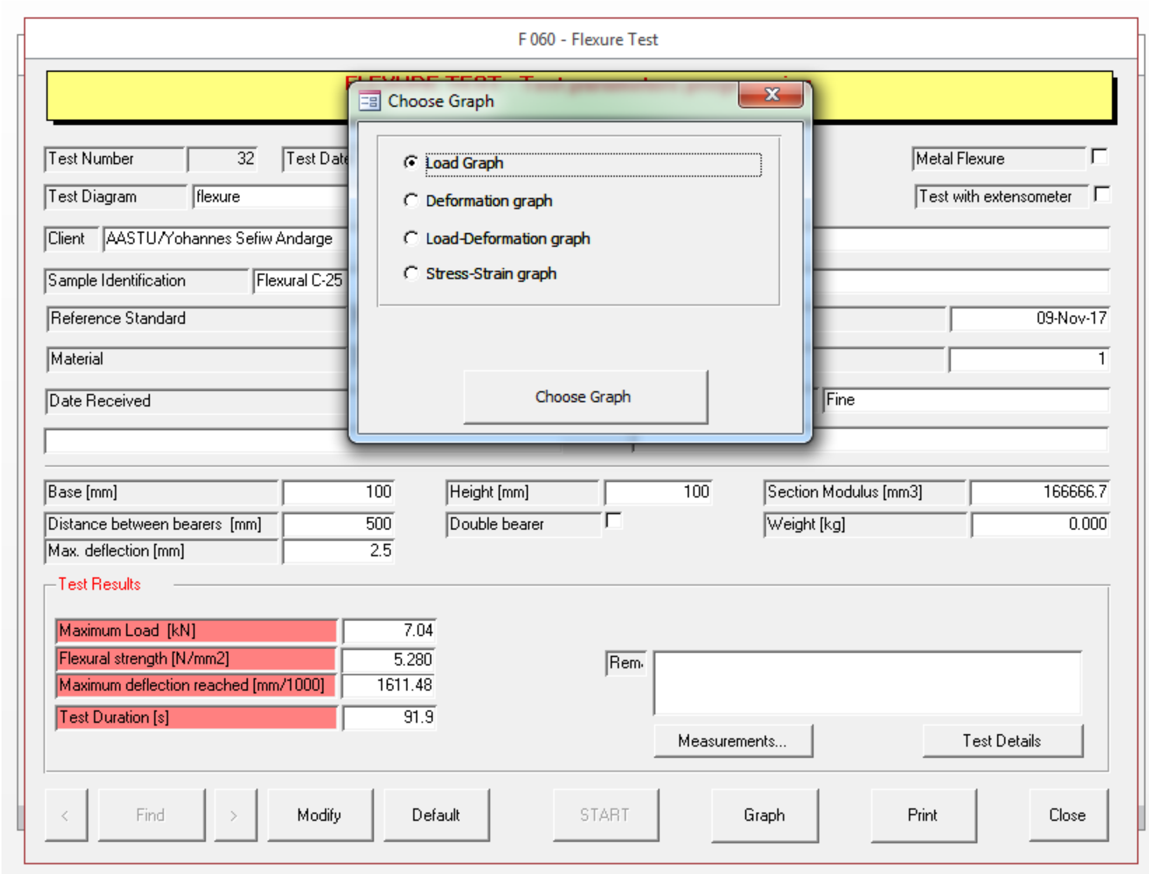


Figure A.23 Choosing of graph types

A.3.2 COMPRESSIVE STRENGTH TEST PROCEDURE

The major procedures to conduct compressive strength test is the same as that flexural strength test with minor differences discussed below.

Step 1 - **Plugged the power socket** (the same as flexural strength test)

Step 2 - **Power on the machine** (the same as flexural strength test)

Step 3 - **Fill the firm address** (the same as flexural strength test)

Step 4 - **Preparation of the machine for flexure test**

The testing machine prepared for compression test as follows:

Step 4.1 - Positioning of the upper platen in its seating situated on the lower face of cross-beam (the platen is locked in position by the knob found on the front of the cross-beam); a fixed platen or one with a ball seat may be chosen, naturally the function of the two types of platens are different: the fixed platen is used for tests on metal cylinders with flat parallel ends which have been machine finished, the ball seated platen is normally used for concrete, cement and rock samples where an initial adaptation of the platen to the sample surface is required when the loaded faces of the sample are not perfectly parallel;

Step 4.2 - Positioning of the lower platen on cross-beam; the choice between the two different diameters should be made in base of that mentioned above.

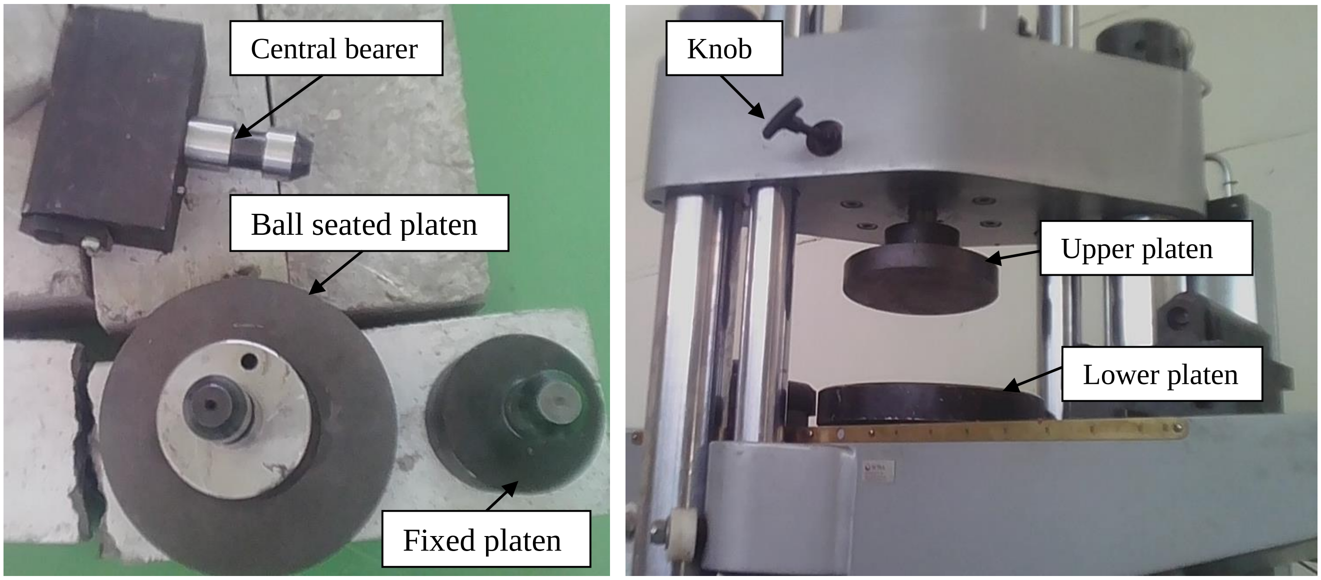


Figure A.24 Preparation of machine for compression test

Step 5 - Preparation of the sample for compressive strength test

The sample is placed on at center of the support and move in the required direction using knob No 4. The knob number 4 in figure 3.14, activates the main hydraulic ram; in the 12 o'clock position the upper gripping head rises and in the 6 o'clock position it descends.

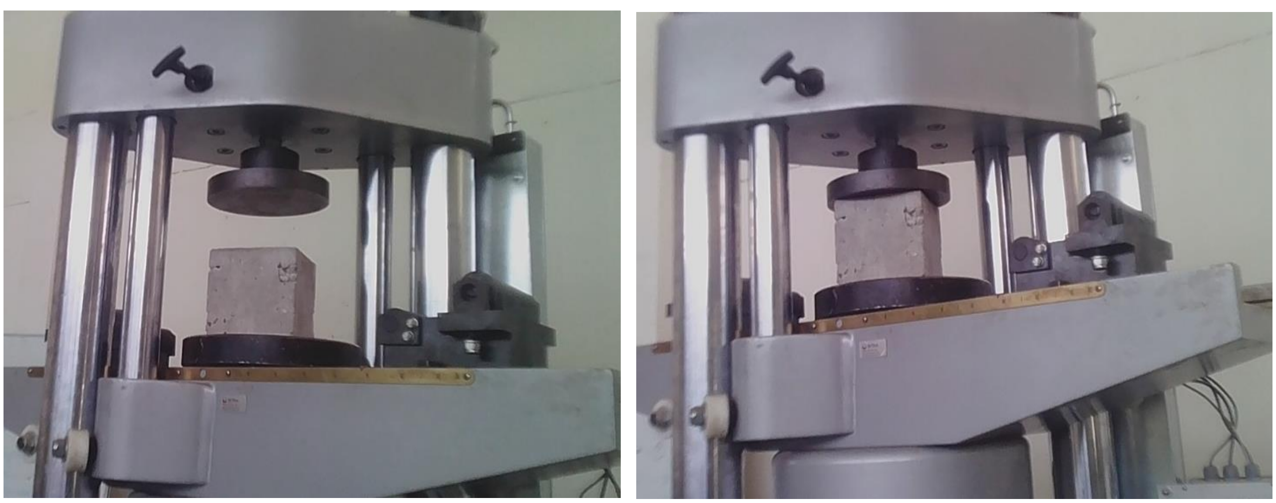


Figure A.25 Preparation of the sample for compressive strength test

Step 6 - Conduct flexural strength test

The compressive strength test conducted as follows:

Step 6.1 - Click on Tecnotest icon on desktop to start the test;

Step 6.2 - Select type of test from dropdown list as "Compression Test" and click "Ok" icon;

Step 6.3 - Enter first level password as "123" and second level as "456" to allow use of test management;

Step 6.4 - Select test management and click "Yes" to continue conducting new test;

Step 6.5 - Fill input data by clicking on "Modify" icon;

Step 6.6 - Click on "START" icon and then click on "Cycle start" to run the test;

Step 6.7 - Save the test result in database by clicking "Ok" icon while the "Test result saved in DataBase" message box appeared immediately at the end of the test;

Step 6.8 - Read or print or snip the test results; the test result may be maximum load, maximum compressive strength, test details and different graphs. To get the graph click on "Graph" icon then choose the type of graphs by clicking "Load Graph", Deformation Graph", Load-Deformation Graph" and "Stress-Strain Graph".

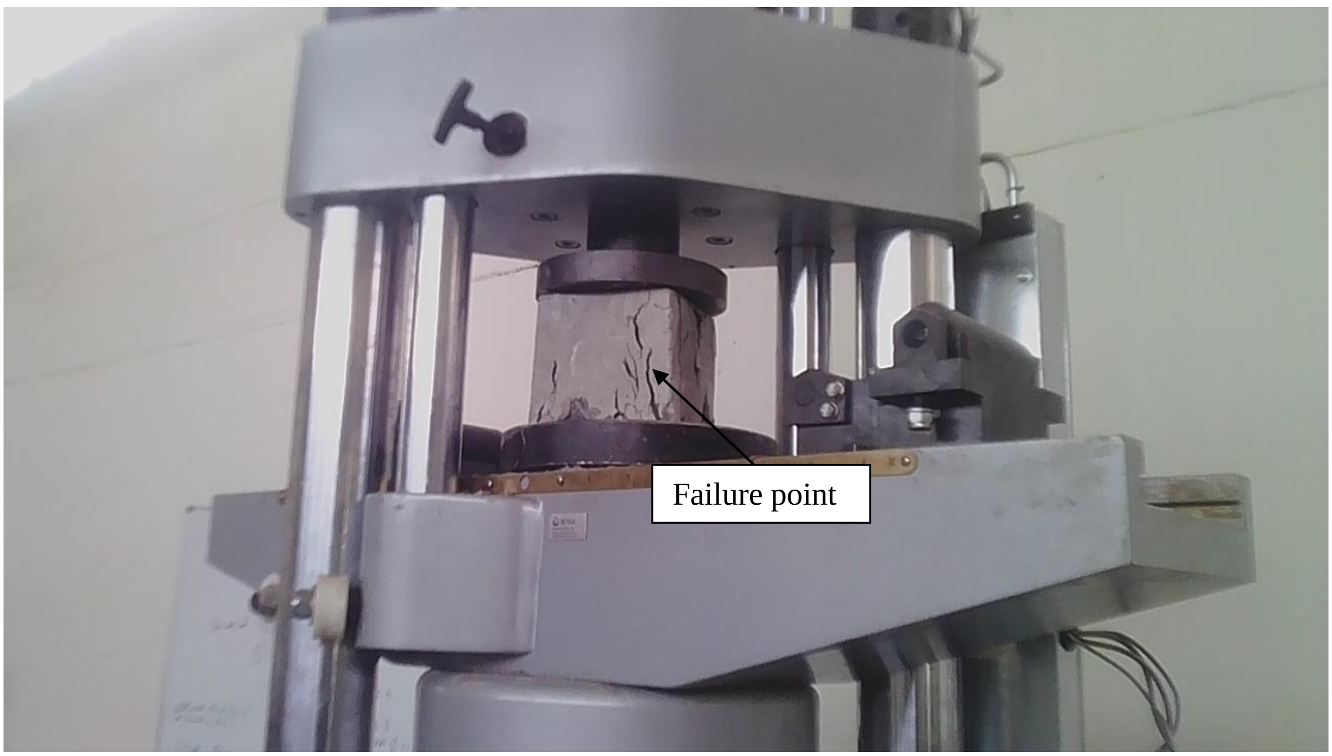


Figure A.26 Fragile failure of the sample for compression test

APPENDIX B - DESIGN OF TYPICAL ARCHITECTURAL FLOOR PLAN

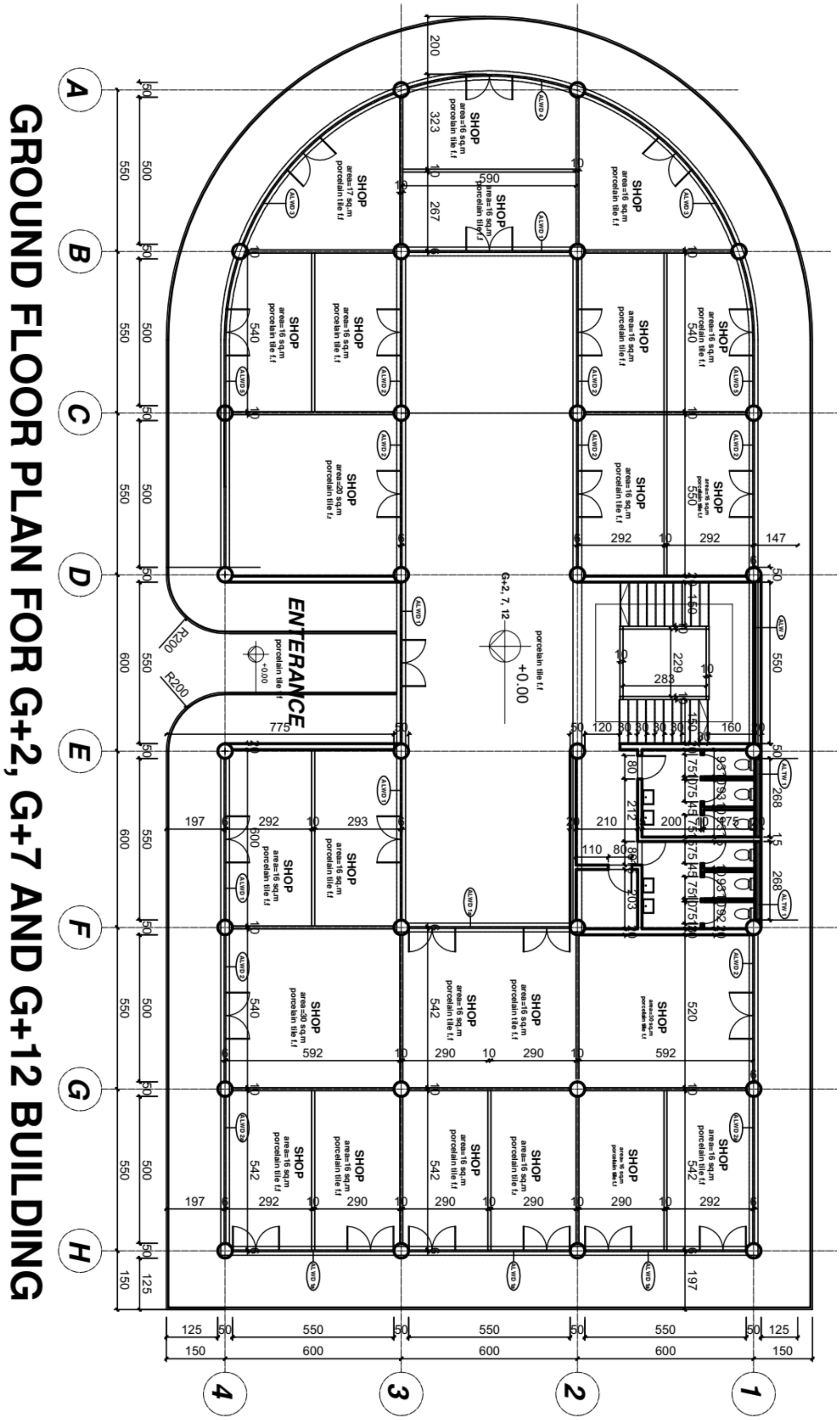


Figure B.1 Ground floor plan for G+2, G+7 and G+12 Buildings

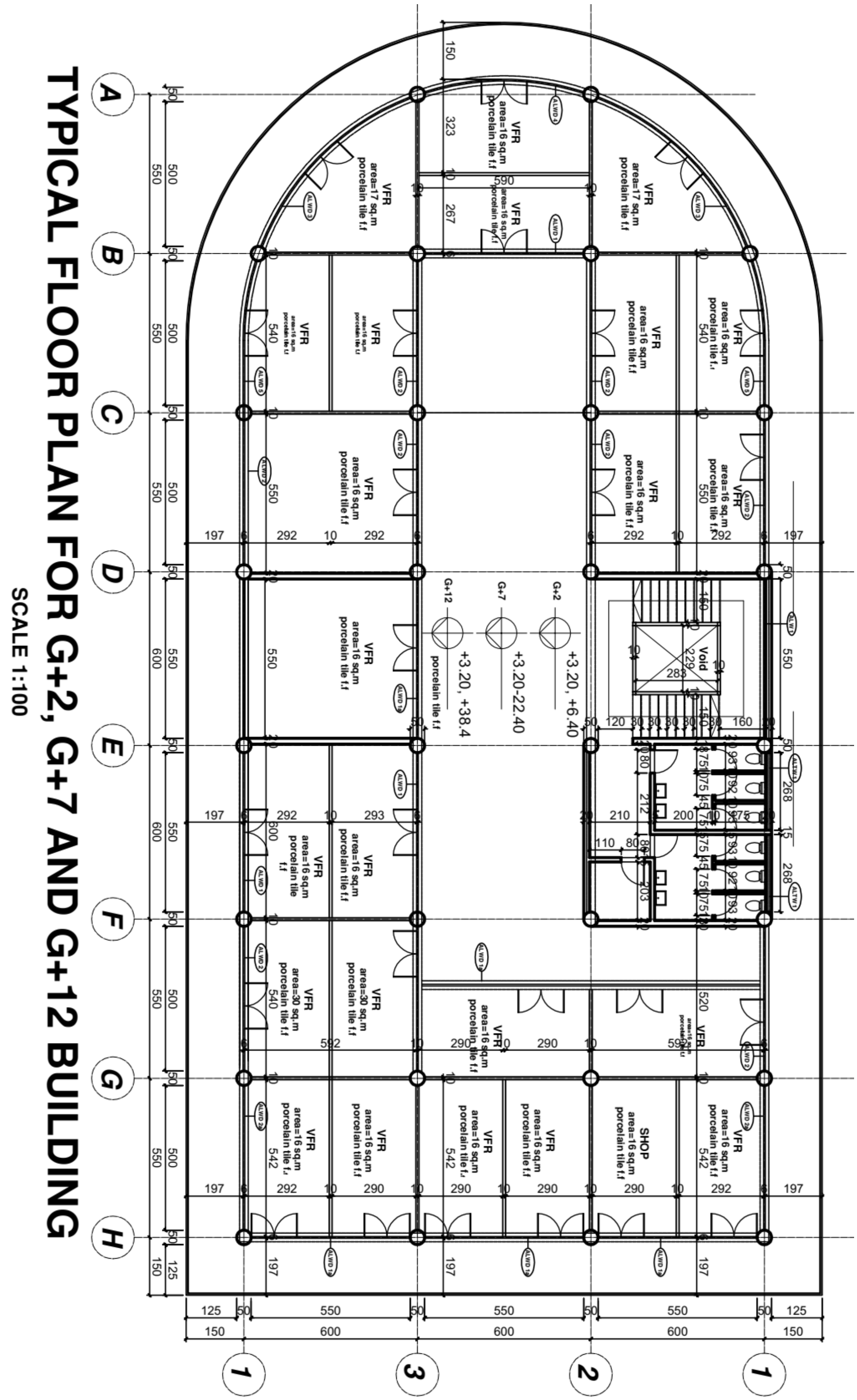


Figure B.2 Typical floor plan for G+2, G+7 and G+12 Buildings

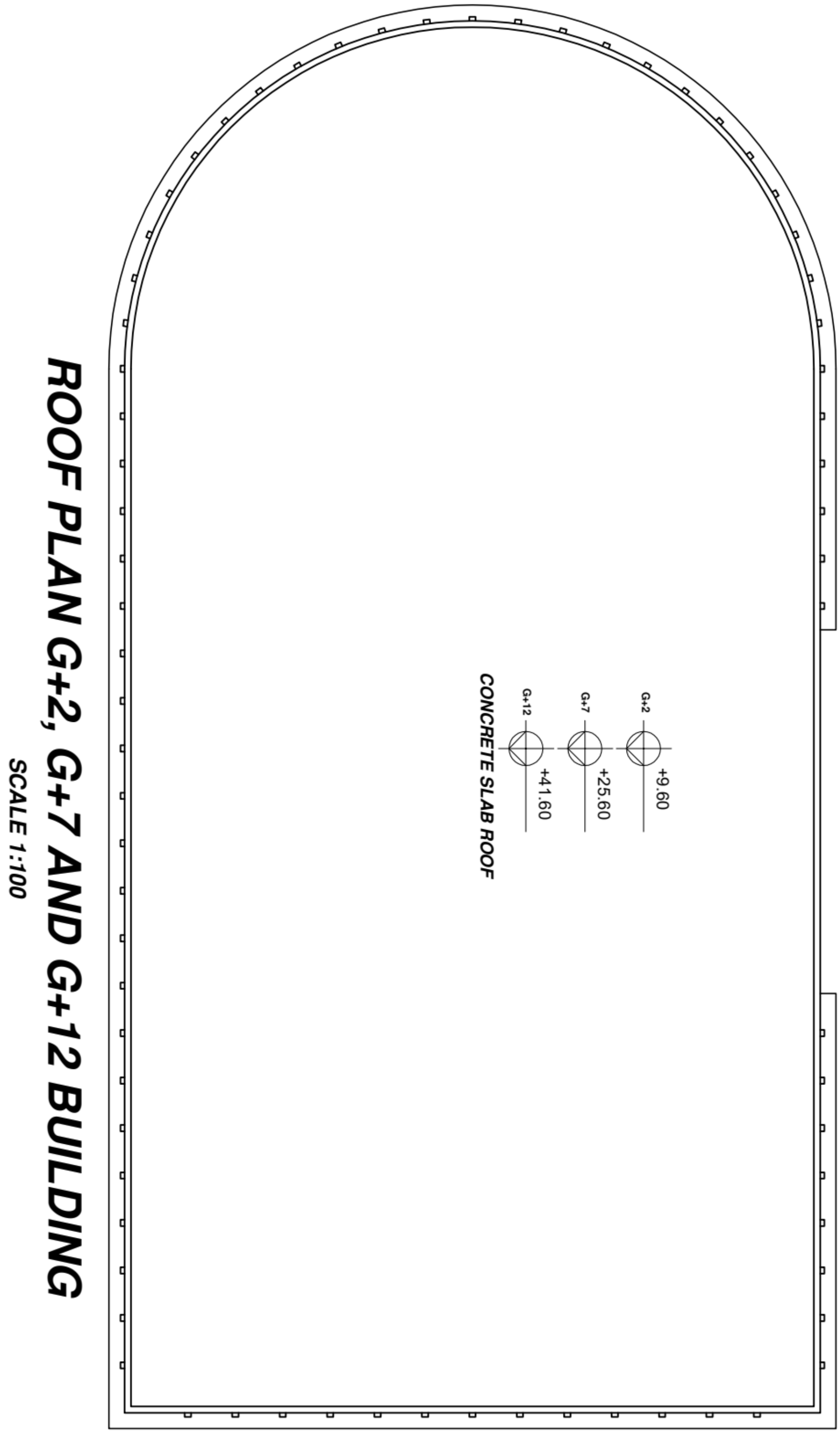


Figure B.3 Roof plan for G+2, G+7 and G+12 Buildings

APPENDIX C - SAMPLE STRUCTURAL DESIGN

C.1 DESIGN SPECIFICATION

The structure is made of reinforced concrete; the main materials that determines the behavior of the structural design is concrete and reinforcing steel.

Concrete: structural concrete can be prepare with different compressive strength depending on the load of the structure starting from C-15 up to C-105 as per table 3.1 on ES EN-2, 2015. The choice of concrete grade depend on various factors like the type of the structure, quality of material, quality of workmanship and other environmental factors. Among these the research uses C-25 (Concrete grade without admixture) and C-40 (Concrete grade with admixture) for floor slabs, beams, foundations, staircase and columns designs to investigate the effect of concrete grade enhancer admixture on structural design of high rise buildings.

Steel: reinforcing steel or rebar also manufactured with different tensile strength; starting from S-240 up to S-600. Again the choice of steel grade depend on the type of structure, quality of material and availability in the market. Now a day there are different type of steel that may be imported from Turk or locally manufacturer; like Kality, Debrezeit, Nazret steel factories with S-275, S-300 and S-400. For this thesis S-300 is used for reinforcing steel to design the structure.

Partial factor of safety for material: According to table 2.1N on ES EN-2, 2015 the corresponding partial factor of safety for material is 1.5 and 1.15 for concrete and reinforcing steel respectively for persistent & transient design situation.

Table C.1 Partial factor for materials for ultimate states

Design situations	γ_c for concrete	γ_s for reinforcing steel
Persistent & Transient	1.5	1.15
Accidental	1.2	1.0

Design strength: the design strength of material computed using the formula shown below;

1. Design concrete strength $f_{cd} = 0.85f_{ck,\,cube} / \gamma_c$ $f_{ctd} = 0.21(f_{ck,\,cube})^{2/3}$

2.Design steel strength $f_{yd} = f_{yk} / \gamma_s$

Partial factor of safety for load: According to table A1.2(B) on ES EN-0, 2015 the partial factor of safety for actions in building structures are 1.35, 1.5 and 1 for persistent, transient and accidental design situations respectively.

C.2 ANALYZING ARCHITECTURAL DESIGN AND STRUCTURAL PLANNING

In engineering, solution is comes after understanding and knowing the real problem; in order to made structural modeling, analysis and design the first step is analyzing and understanding the architectural design to propose serviceable, strong and economical building to investigate the effect of concrete grade enhancer admixture on structural design of high rise building accurately.

Then, after fully understanding the architectural design; the next task is decide on the structural layout of the building. Structural planning is a means of deciding the layout or the skeleton of the building, which include fixing the position of beams, columns, slabs, foundations and other structural element with their connection each other. Simply it is a means of deciding the 3D model of the entire frame system. In such activity adding, removing, and changing different structural elements may be done from the prepared typical architectural design.

After analyzing and fully understand the architectural design the structural layout for G+2, G+7 and G+12 buildings shown in the figure below.

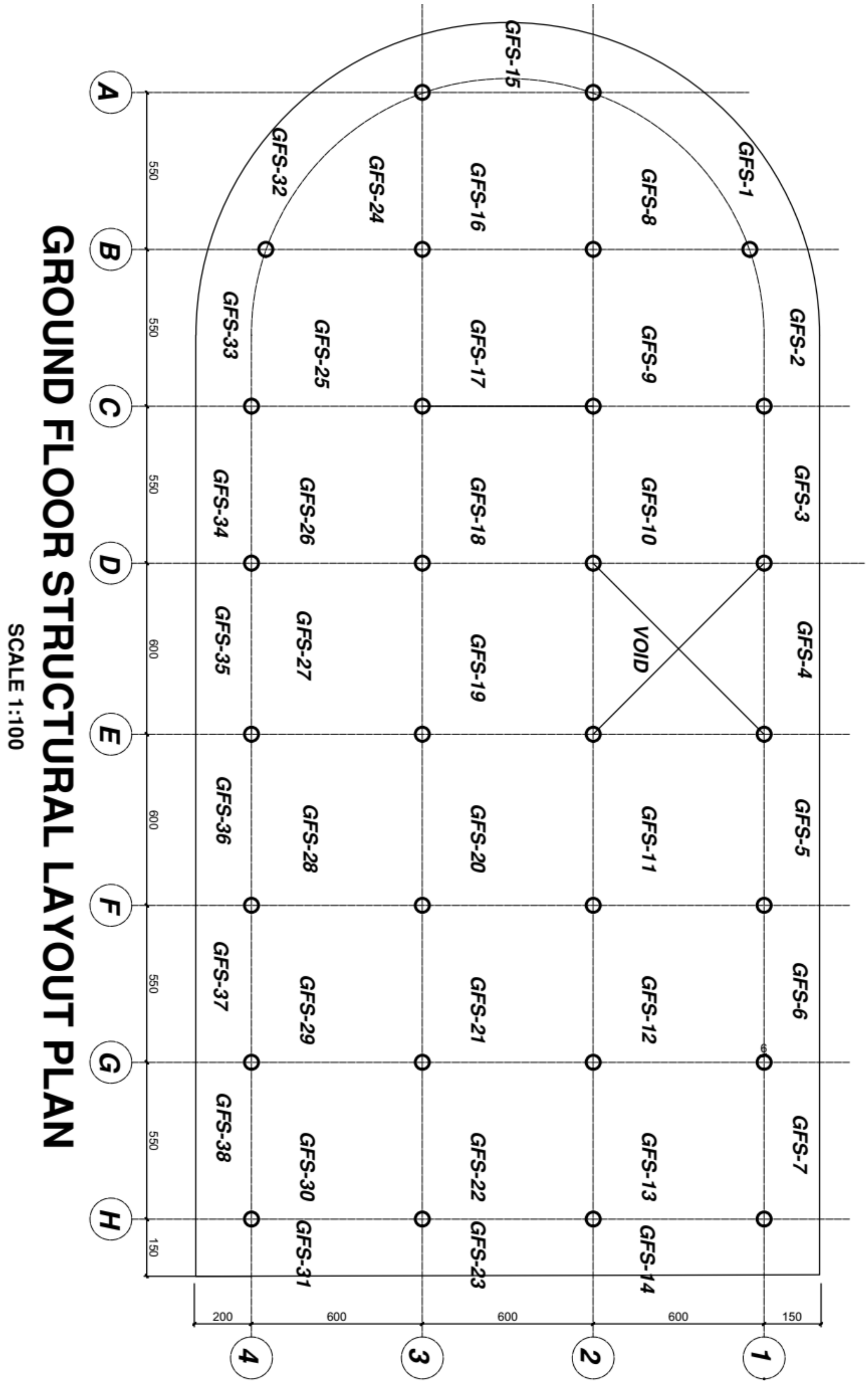


Figure C.1 Ground floor structural layout plan for G+2, G+7 & G+12

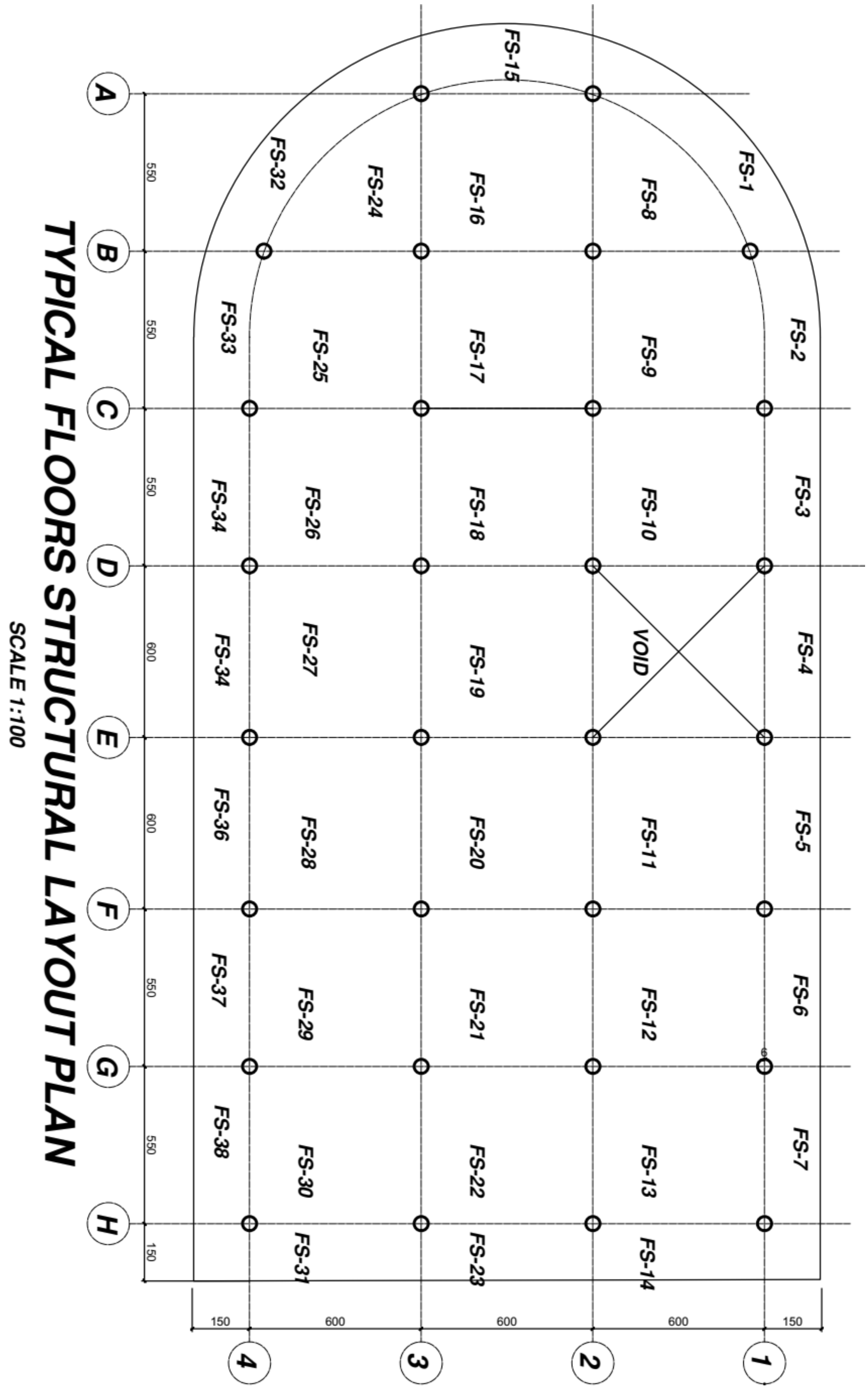


Figure C.2 Typical floors structural layout plan for G+2, G+7 & G+12

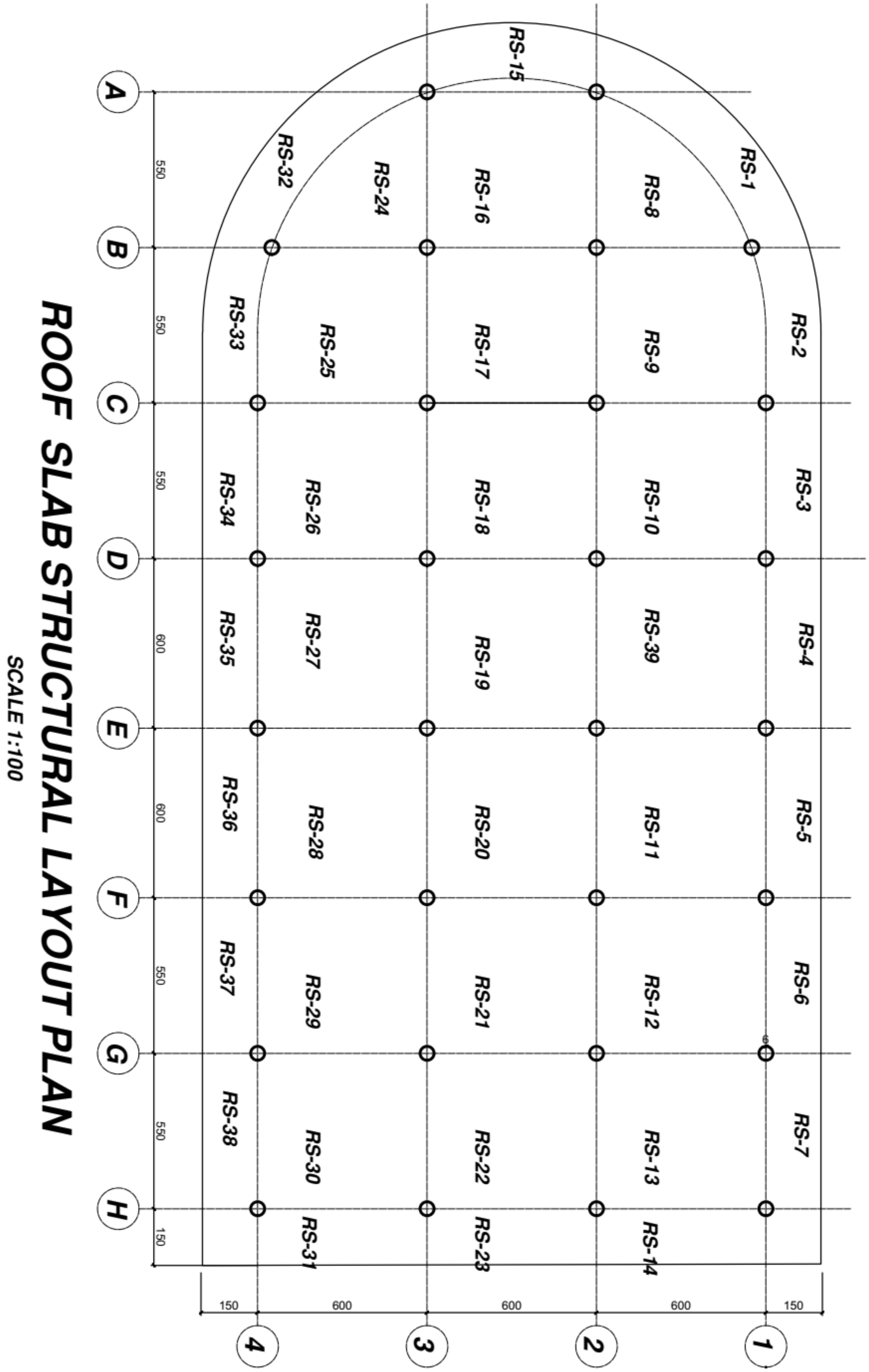


Figure C.3 Roof slab structural layout plan for G+2, G+7 & G+12

C.3 FRAME LATERAL LOAD ANALYSIS

Frame is the interconnected system that is formed by the monolithic connection of beams and columns with foundation as support. Any frame system suffered for lateral load like earth quake and wind loads. Thus, here in this section wind and earthquake load are analyzed for the entire frame system based on ES EN 1 and ES EN 8: 2015.

C.3.1 WIND LOAD ANALYSIS

C.3.1.1 WIND LOAD ANALYSIS FOR G+2 BUILDING

<u>Step 1</u> Basic velocity pressure :(q_b)

$V_b = V_{b,o}\, C_{dir} * C_{season}$……………………………………..……………...……….. .Equation 4.1 ES EN 1: 2015

$q_b = 0.5 * \rho * V_b^2$……………………………………………………………………. Equation 4.10 ES EN 1: 2015

Where:

$V_{b,o}$ is the fundamental value of the basic wind velocity which is given in the National Annex; since National Annex for Ethiopia is not amended use 22m/s;

C_{dir} is the direction factor which is given in the National Annex; recommended value is 1;

C_{season} is the season factor which is given in the National Annex; recommended value is 1;

ρ is the air density, which depends on the altitude, temperature and barometric pressure to be expected in the region during wind storm that given on National Annex; recommended value is $1.25 kg/m^3$;

$V_b = 22m/s*1*1=$**<u>22m/s</u>**

$q_b = 0.5 * 1.25\ kg/m^3 * (22m/s)^2 = 302.5\ N/m^2 =$ **<u>$0.3025 KN/m^2$</u>**

<u>Step 2</u> Reference height: (Z_e)

According to ES EN 1: 2015 figure 7.4 the reference height, Z_e for walls of rectangular plan buildings depends on the aspect ratio h/b.

1. Buildings, whose height h is less than b, shall be considered to be one part.
2. Buildings, whose height h is greater than b, but less than 2b, shall be considered to be two parts.
3. Buildings, whose height h is greater than 2b, shall be considered to be in multiple parts.

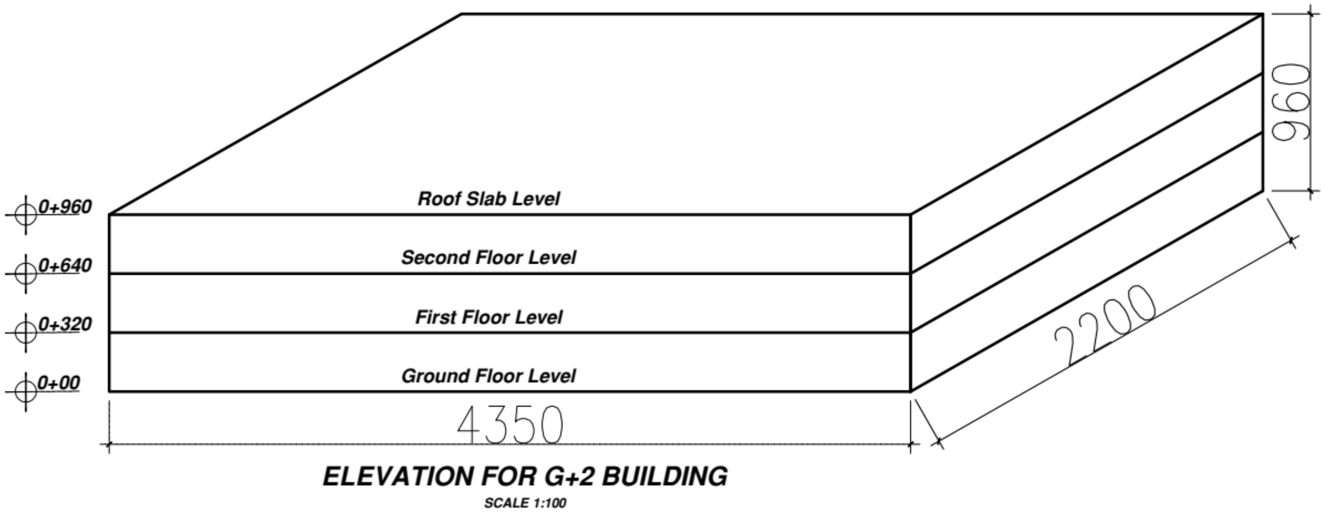


Figure C.4 Elevation of G+2 Building

Height of the building, h = 9.60m and b = 43.5m when the wind blows in x direction and b = 22m when the wind blow in y direction. Since in both case h < b, thus Z_e= h = 15m and consider as one part.

Step 3 Exposer coefficient: (C_e(z))

The exposer factor C_e(z) is illustrated in figure 4.2 on ES EN 1, 2015 as a function of height above terrain category.

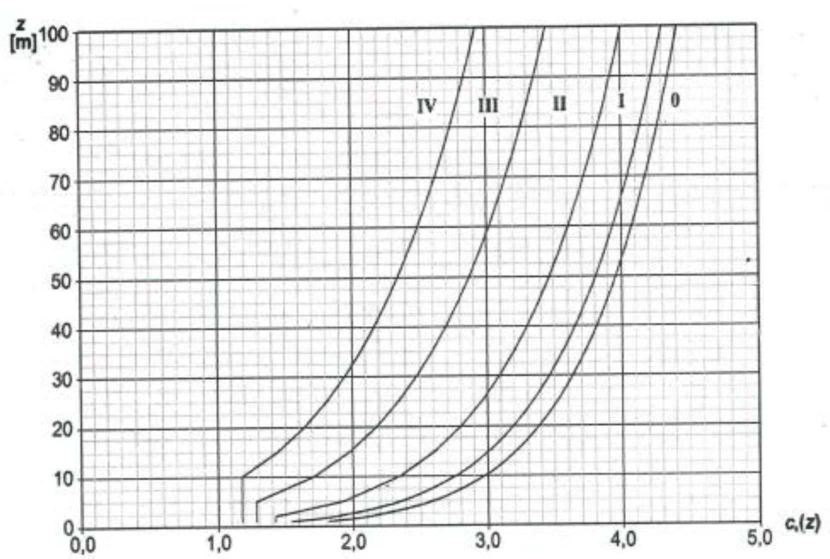


Figure C.5 Graph for exposer coefficient

Based on table 4.1 the terrain category for Semera is terrain category II; thus using figure 5.5 the exposer coefficient for terrain category II with building height of 9.6m is 2.31

Thus, C_e(z) = **2.31**

Step 4 Characteristic peak velocity pressure :(q_p)

$q_p = C_e(z).q_b$……………………………………………………………...…Equation 4.8 ES EN 1: 2015

q_p = 2.31*0.3025KN/m^2 = **0.7KN/m^2**

Step 5 Determine external pressure coefficient: C_{pe} (z)

The external wind pressure computed using table 7.1 on ES EN 1: 2015 based on the wall area. For vertical rectangular panel there two possible direction of wind; either in the x or y direction. Thus analysis is done for both case and the maximum case is used for design. According to ES EN 1: 2015 section 7.2 the external pressure coefficient is computed as follow;

$C_{pe} = C_{pe,1}$ for $A < 1m^2$

$C_{pe} = C_{pe,1} + (C_{pe,10} - C_{pe,1})\log_{10}{}^{A}$ for $1m^2 < A < 10m^2$ and

C_{pe} = Cpe,10 for $A > 10m^2$

For wind blows normal to X direction (Longer wall)

e = min (b, 2h) = min (43.5, 2*9.6) = **19.2m**

d = 22m > e = 19.5m, thus the elevation for e < d according to figure 7.5 on ES EN 1: 2015 is;

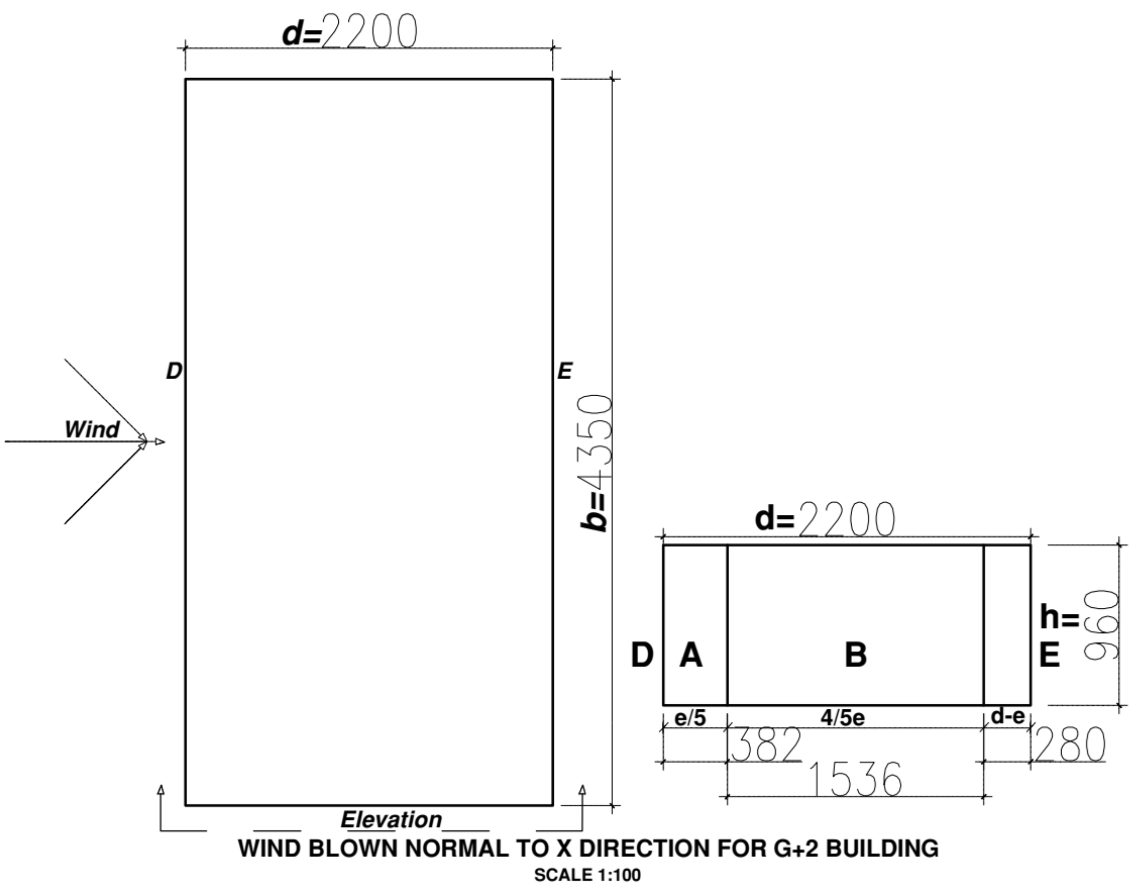


Figure C.6 Windblown normal to X direction for G+2 building

Area of wind regions and External pressure coefficient in x direction summary in the table shown below; h/d = 9.6/22 = **0.436**

Table C.2 External pressure coefficient for wall normal to X direction for G+2 building

Zone	A	B	C	D	E
width (m)	3.84	15.36	2.80	43.5	43.5
Height (m)	9.6	9.6	9.6	9.6	9.6
Area (m^2)	36.84	147.46	26.88	417.6	417.6
C_{pe}	-1.2	-0.8	-0.5	+0.74	-0.39

For wind blows normal to Y direction (Shorter wall)

e = min (b, 2h) = min (22, 2*9.6) = **19.2m**

d = 43.5m > e = 19.2m, thus the elevation for d > e according to figure 7.5 on ES EN 1, 2015 is;

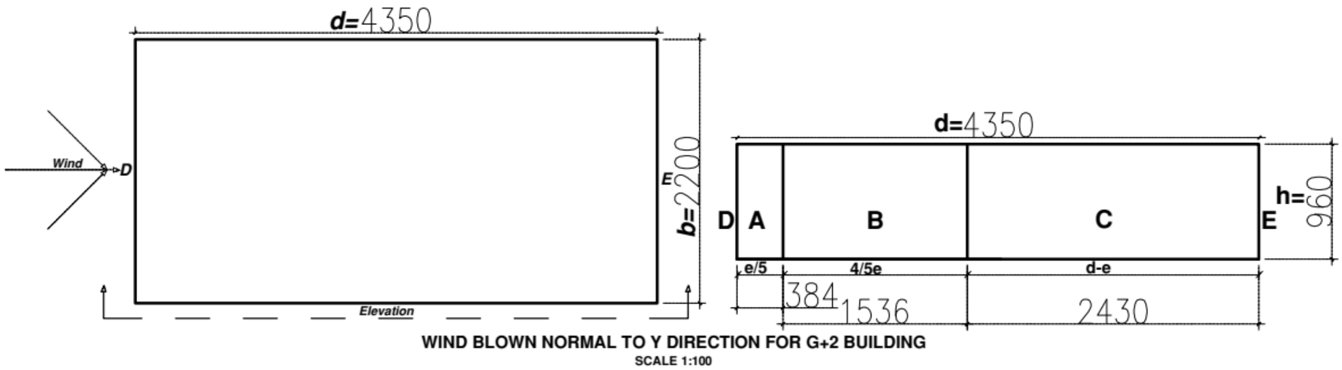


Figure C.7 Windblown normal to Y direction for G+2 building

Area of wind regions and External pressure coefficient in x direction summary in the table shown below; h/d = 9.6/43.5 = **0.22**

Table C.3 External pressure coefficient for wall normal to Y direction for G+2 building

Zone	A	B	C	D	E
width (m)	3.84	15.36	24.30	22	22
Height (m)	9.6	9.6	9.6	9.6	9.6
Area (m^2)	36.84	147.46	233.28	211.2	211.2
C_{pe}	-1.2	-0.8	-0.5	+0.7	-0.3

Step 6 Internal pressure coefficient:

The internal pressure coefficient, C_{pi}, depends on the size and distribution of opening in the building envelope. According to figure 7.13 on ES EN 1: 2015 the internal pressure coefficient can be determined using height depth ratio and opening ratio. Moreover section 7.2.9, Note 2 on ES EN 1: 2015 where it is not possible or not considered justified to estimate opening ratio μ, for a particular case the C_{pi} should be taken as the more onerous of +0.2 and -0.3. Thus, let us use the internal pressure coefficient as +0.2 and -0.3.

<u>Step 6</u> Net wind pressure:

$W_e = q_p(z)C_{pe}$……………………………………………………………Equation 5.1 ES EN 1: 2015
$W_i = q_p(z)C_{pi}$ ……………………………………………………………Equation 5.2 ES EN 1: 2015
$W_{net} = W_e - W_i$, from step 4 $q_p = 0.7 KN/m^2$

Table C.4 Net pressure for G+2 building wall

Zone	Normal to X direction (Longer wall)					Normal to Y direction(Shorter wall)				
	A	B	C	D	E	A	B	C	D	E
C_{pe}	-1.20	-0.80	-0.50	0.74	-0.39	-1.20	-0.80	-0.50	0.70	-0.30
C_{pi}^-	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30
C_{pi}^+	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
W_e	-0.84	-0.56	-0.35	0.52	-0.27	-0.84	-0.56	-0.35	0.49	-0.21
Wi^+	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Wi^-	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21	-0.21
W_e-W_i^+	-0.98	-0.70	-0.49	0.38	-0.41	-0.98	-0.70	-0.49	0.35	-0.35
W_e-W_i^-	-0.63	-0.35	-0.14	0.73	-0.06	-0.63	-0.35	-0.14	0.70	0.00

Therefore, the maximum negative and positive wind pressures among all possible wind direction for design purpose are;

W_{net}^- = **<u>-0.98 KN/m²</u>** (suction) W_{net}^+ = **<u>0.7KN/m²</u>** (pressure)

<u>Step 7</u>: Wind Force

The uniformly distributed area wind load should be transfer to frame either as concentrated or line load. Here the longer direction choose as wind blow direction. Thus, the shorter direction suffer for suction the longer direction for pressure.

$F_{w,e} = C_sC_d \sum w_e A_{ref}$……………………………………………………Equation 5.6 ES EN 1: 2015
$F_{w,i} = \sum w_i A_{ref}$……………………………………………………………Equation 5.6 ES EN 1: 2015
$F_{net} = F_{w,e} - F_{w,i}$ $F_{net} = W_{net} A_{ref}$

Where,

C_sC_d is structural factor, which is 1 for building height less than 100m;
A_{ref} is a reference area of a structure or a structural element;

Accordingly the wind force on the joint of the frame computed as follow shown in the table below.

Table C.5 Wind forces for G+2 Building

Notation	Wind type	W (KN/m^2)	h(m)	b(m)	A_{ref} (m^2)	F_w (KN)
F_{w1}	suction	-0.98	3.2	3.75	12.0	-11.76
F_{w2}	suction	-0.98	3.2	5.5	17.6	-17.248
F_{w3}	suction	-0.98	3.2	5.75	18.4	-18.032
F_{w4}	suction	-0.98	3.2	6	19.2	-18.816
F_{w5}	pressure	0.7	3.2	4	12.8	8.96
F_{w6}	pressure	0.7	3.2	6	19.2	13.44

Note: the area of the load at the joint is take as half from one side half from other side (i.e b = (b_1+b_2)). For example for F_{w2}, b = (5.5+5.5)/2 = 5.5m.

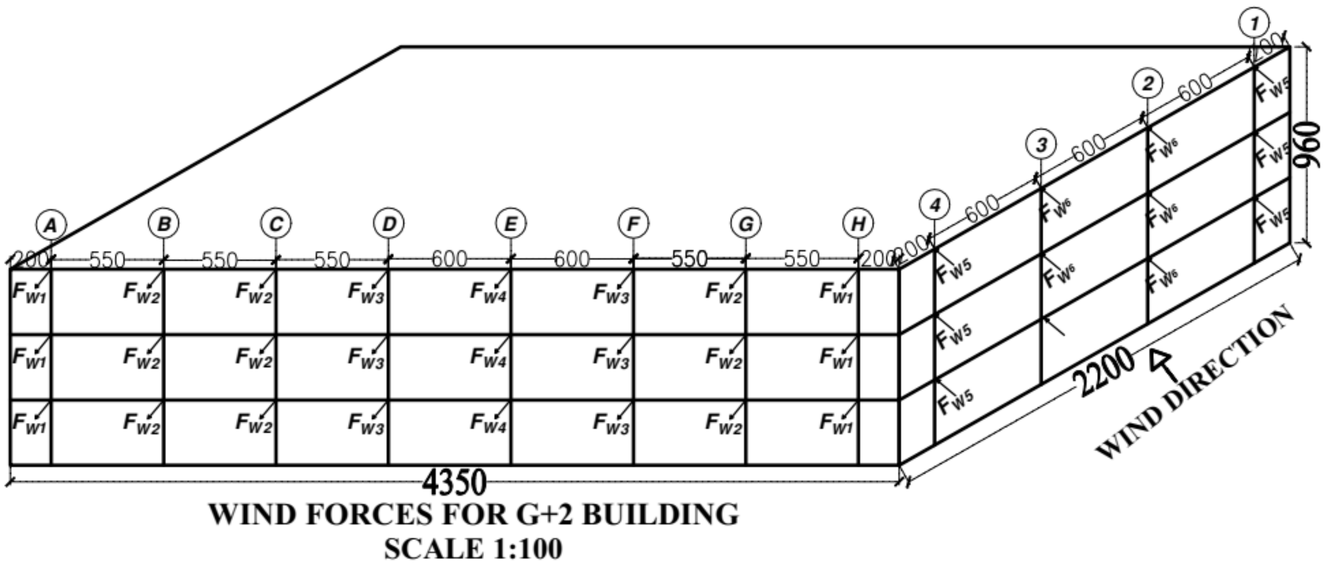


Figure C.8 Wind forces for G+2 Building

Following similar procedure used for wind load analysis for G+2 building; the wind load is computed for G+7 and G+12 building as shown below.

C.3.1.2 WIND LOAD ANALYSIS FOR G+7 BUILDING

<u>Step 1</u> Basic velocity pressure :(q_b)

V_b = 22m/s*1*1=**<u>22m/s</u>** (The same as the previous work)

q_b = **<u>0.3025KN/m^2</u>** (The same as the previous work)

<u>Step 2</u> Reference height: (Z_e)

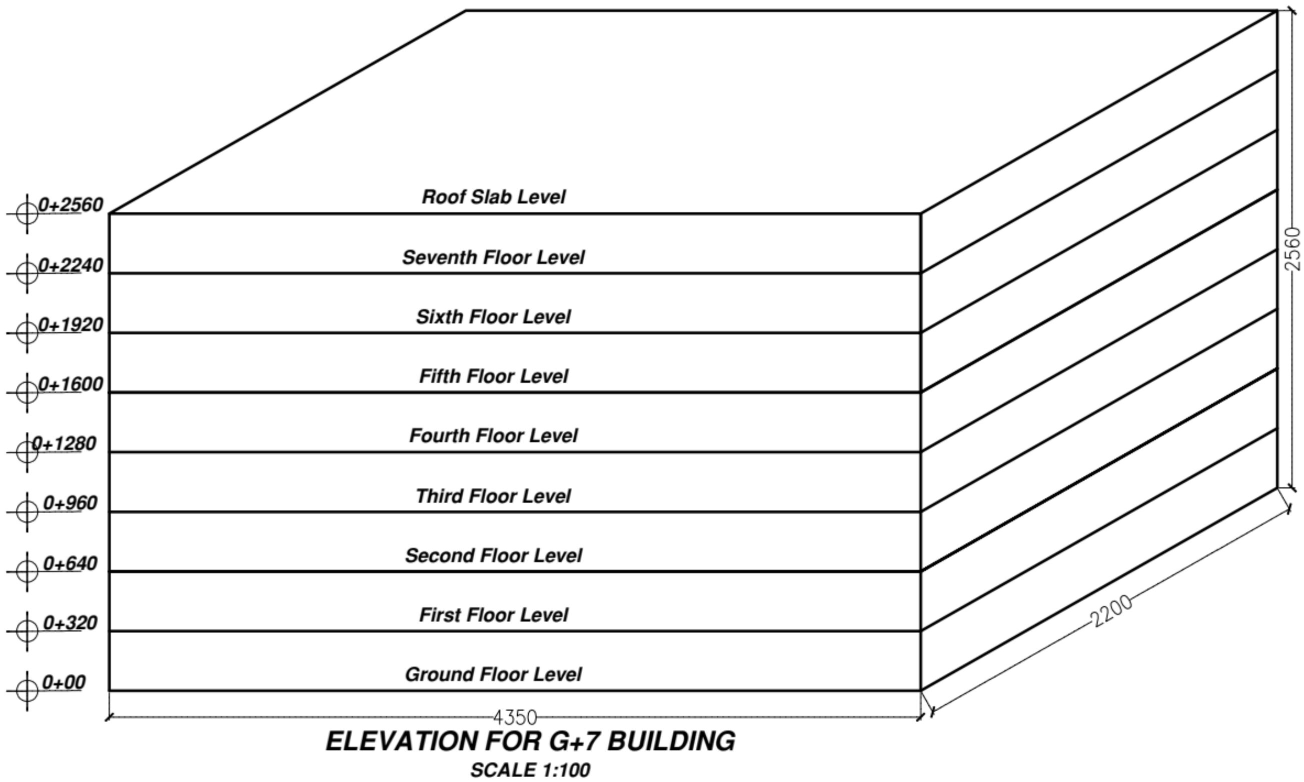


Figure C.9 Elevation of G+7 Building

Height of the building, h = 25.6m and b = 43.5m when the wind blows normal to X direction and b = 22m when the wind blow in Y direction. Thus, Z_e = h = 25.6m since, h < b when the wind blows normal to X direction and consider as one part and Z_e = b = 22m and Z_e = h = 25.6m since, b < h < 2b when the wind blows normal to Y direction and consider as two part.

<u>Step 3</u> Exposer coefficient: ($C_e(z)$)

Similarly as the previous work using figure 5.5, the exposer coefficient for terrain category II with reference of height of 25.6m and 22m is 2.96 and 2.84.

Thus, $C_e(z)$ = **<u>2.96</u>** for Z_e = h = **<u>25.6m</u>**

$C_e(z)$ = **<u>2.84</u>** for Z_e = b = **<u>22m</u>**

<u>Step 4</u> Characteristic peak velocity pressure :(q_p)

q_p = 2.96*0.3025KN/m^2 = **<u>0.895KN/m^2</u>** for Z_e = 25.6m (when the wind blown normal to X direction)

q_p = 2.96*0.3025KN/m^2 = **<u>0.895KN/m^2</u>** for Z_e = 25.6m (when the wind blown normal to Y direction)

q_p = 2.84*0.3025KN/m^2 = **<u>0.859KN/m^2</u>** for Z_e = 22m (when the wind blown normal to Y direction)

<u>Step 5</u> Determine external pressure coefficient: C_{pe} (z)

<u>For wind blows normal to X direction (Longer wall)</u>

e = min (b, 2h) = min (43.5, 2*25.6) = **<u>43.5m</u>**

d = 22m < e = 43.5m, thus the elevation for e > d according to figure 7.5 on ES EN 1: 2015 is;

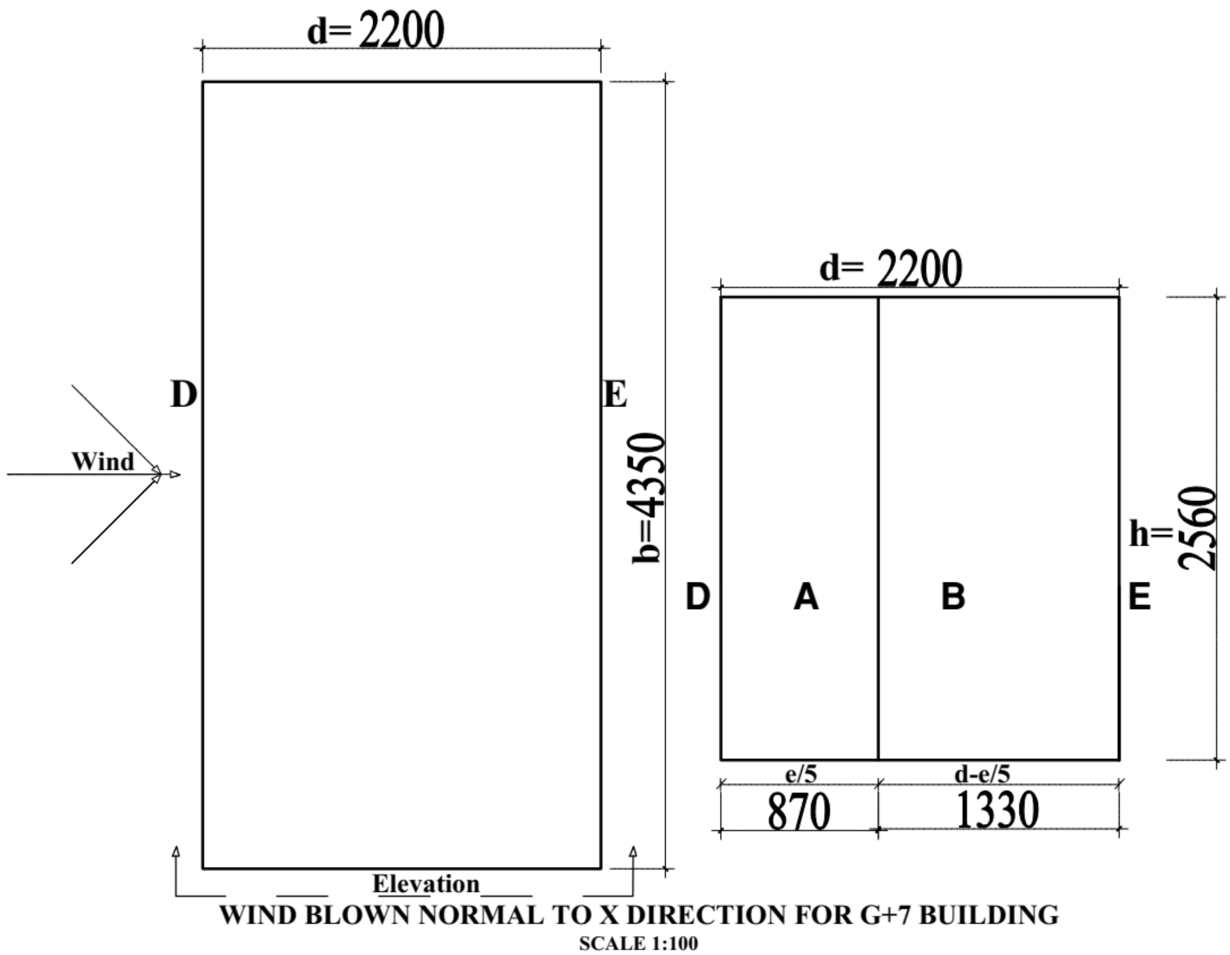


Figure C.10 Windblown normal to X direction for G+7 building

Area of wind regions and Exsternal pressure coefficient in x direction summary in the table shown below; h/d = 25.6/22 = **<u>1.16</u>**

Table C.6 External pressure coefficient for wall normal to X direction for G+7 building

Zone	A	B	D	E
For Z_e = h = 25.6m and h/d = 1.16				
width (m)	8.7	13.3	43.5	43.5
Height (m)	25.6	25.6	25.6	25.6
Area (m^2)	222.72	340.48	1113.6	1113.6
C_{pe}	-1.2	-0.8	+0.8	-0.54

For wind blows normal to Y direction (Shorter wall)

e = min (b, 2h) = min (22, 2*25.6) = **22m**

d = 43.5m > e = 22m, thus the elevation for d > e according to figure 7.5 on ES EN 1, 2015 is;

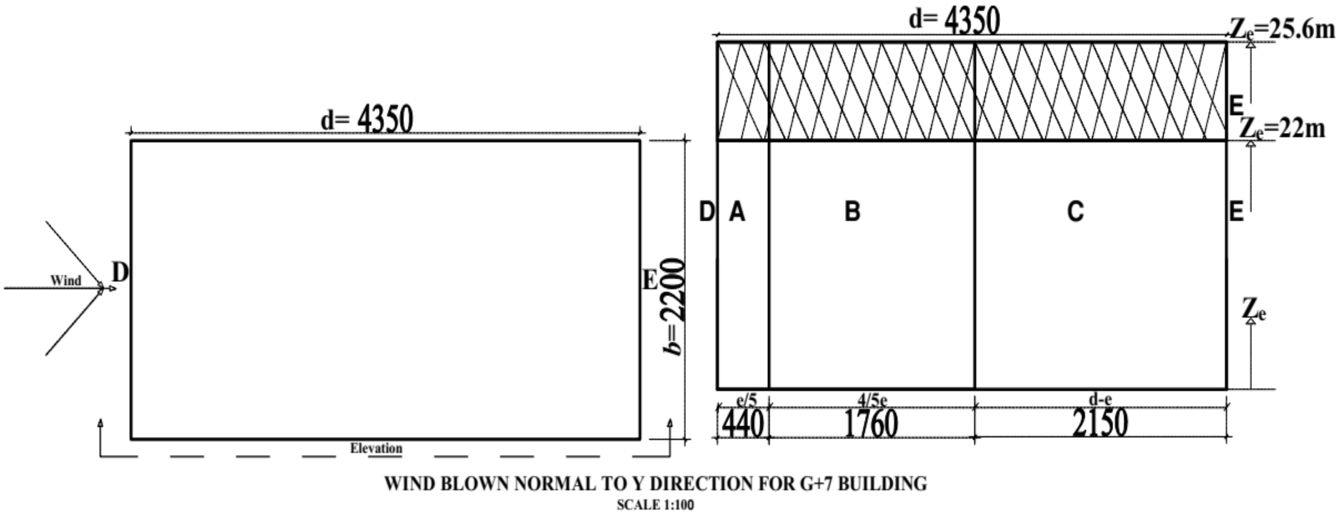


Figure C.11 Windblown normal to Y direction for G+7 building

Area of wind regions and External pressure coefficient in x direction summary in the table shown below; h/d = 22/43.5 = **0.506** for Z_e = 22m and h/d = 25.6/43.5 = **0.59** for Z_e = 25.6m

Table C.7 External pressure coefficient for wall normal to Y direction for G+7 building

Zone	A	B	C	D	E
For Z_e = b = 22m and h/d = 0.506					
width (m)	4.4	17.6	21.5	22	22
Height (m)	22	22	22	22	22
Area (m^2)	96.8	387.2	473	484	484
C_{pe}	-1.2	-0.8	-0.5	0.78	-0.37
For Z_e = h = 25.6m and h/d = 0.59					
width (m)	4.4	17.6	21.5	22	22
Height (m)	25.6	25.6	25.6	25.6	25.6
Area (m^2)	112.64	450.56	550.4	563.2	563.2
C_{pe}	-1.2	-0.8	-0.5	0.79	-0.38

Step 6 Internal pressure coefficient:

Similarly as the previous work the extreme values internal pressure coefficient are +0.2 and -0.3.

Thus, C_{pi}^{-} = -0.3

C_{pi}^{+} = +0.2

<u>Step 6</u> Net wind pressure:

Table C.8 Net pressure for G+7 building wall

Zone	Normal to X direction (Longer wall)					Normal to Y direction(Shorter wall)				
	A	B	C	D	E	A	B	C	D	E
C_{pe} (Z_e=25.6m)	-1.20	-0.80	-0.50	0.80	-0.54	-1.20	-0.80	-0.50	0.79	-0.38
C_{pe} (Z_e=22m)	-	-	-	-	-	-1.20	-0.80	-0.50	0.78	-0.37
C_{pi}^-	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30
C_{pi}^+	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
W_e (Z_e=25.6m)	-1.07	-0.72	-0.45	0.72	-0.48	-1.07	-0.72	-0.45	0.71	-0.34
W_e (Z_e=22m)	-	-	-	-	-	-1.03	-0.69	-0.43	0.67	-0.32
Wi^+ (Z_e=25.6m)	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Wi^+ (Z_e=22m)	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Wi^- (Z_e=25.6m)	-0.27	-0.27	-0.27	-0.27	-0.27	-0.27	-0.27	-0.27	-0.27	-0.27
Wi^- (Z_e=22m)	-0.26	-0.26	-0.26	-0.26	-0.26	-0.26	-0.26	-0.26	-0.26	-0.26
W_e-W_i^+ (Z_e=25.6m)	-1.25	-0.90	-0.63	0.54	-0.66	-1.25	-0.90	-0.63	0.53	-0.52
W_e-W_i^+ (Z_e=22m)	-	-	-	-	-	-1.21	-0.87	-0.61	0.49	-0.50
W_e-W_i^- (Z_e=25.6m)	-0.81	-0.45	-0.18	0.98	-0.21	-0.81	-0.45	-0.18	0.98	-0.07
W_e-W_i^- (Z_e=22m)	-	-	-	-	-	-0.77	-0.43	-0.17	0.93	-0.06

W_{net}^- (Z_e=25.6m) = **<u>-1.25 KN/m²</u>** (suction)

W_{net}^- (Z_e=22m) = **<u>-1.21 KN/m²</u>** (suction)

W_{net}^+ (Z_e=25.6m) = **<u>0.98KN/m²</u>** (pressure)

W_{net}^+ (Z_e=22m) = **<u>0.93KN/m²</u>** (pressure)

<u>Step 7</u>: Wind Force

Following similar procedure as the previous work for G+2 building, the wind forces for G+7 building computed as follow shown in the table below.

Table C.9 Wind forces for G+7 Building

Notation	Wind type	W (KN/m²)	h(m)	b(m)	A_{ref} (m²)	F_w (KN)	Remark
F_{w1}	suction	-1.25	3.20	3.75	12.00	-15.00	Z_e = 25.6m
F_{w2}	suction	-1.25	3.20	5.50	17.60	-22.00	
F_{w3}	suction	-1.25	3.20	5.75	18.40	-23.00	
F_{w4}	suction	-1.25	3.20	6.00	19.20	-24.00	
F_{w5}	pressure	0.93	3.20	4.00	12.80	11.90	Z_e = 22m
F_{w6}	pressure	0.93	3.20	6.00	19.20	17.86	
F_{w7}	pressure	0.98	3.20	4.00	12.80	12.54	Z_e = 265.6m
F_{w8}	pressure	0.98	3.20	6.00	19.20	18.82	

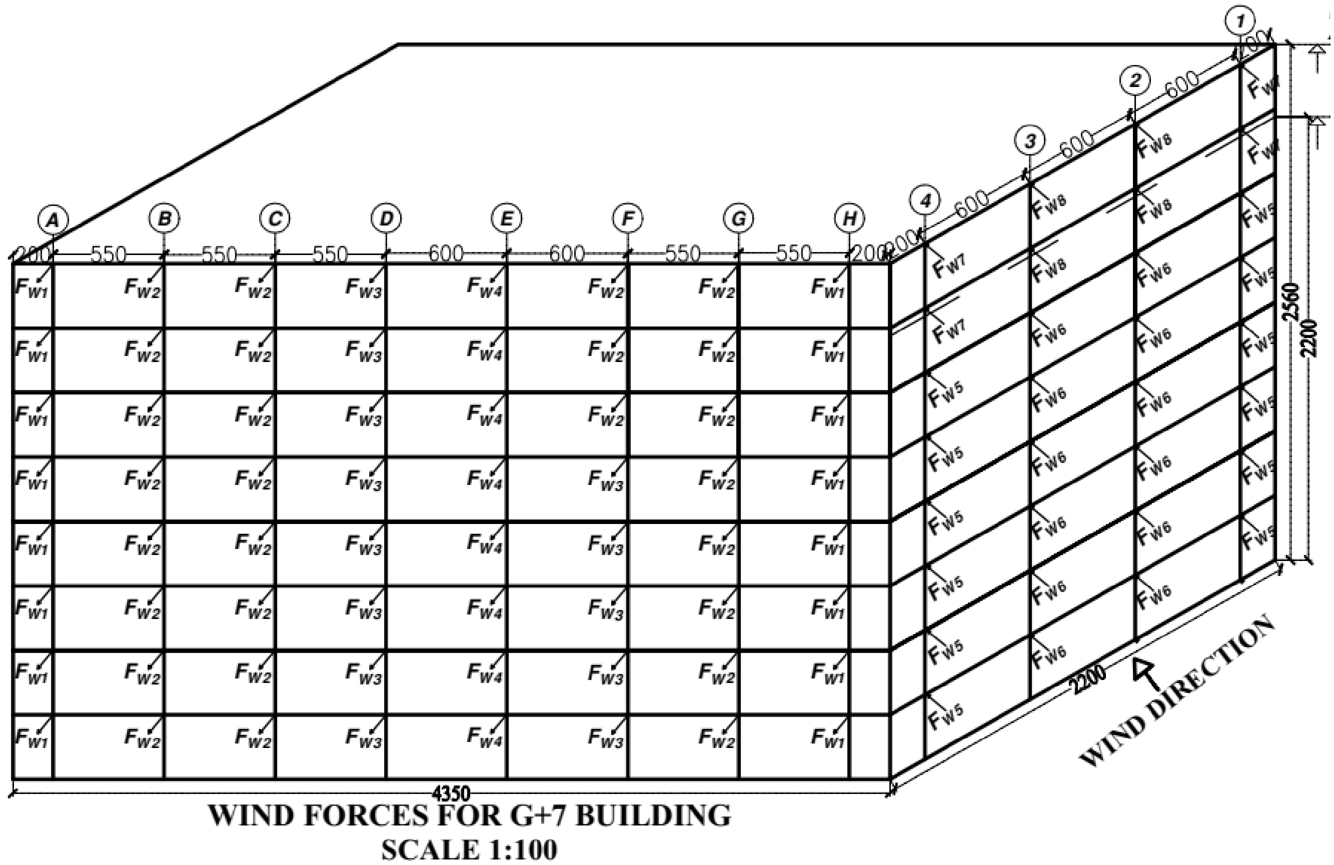


Figure C.12 Wind forces for G+7 Building

C.3.1.3 WIND LOAD ANALYSIS FOR G+12 BUILDING

<u>Step 1</u> Basic velocity pressure :(q_b)

V_b = 22m/s*1*1=**<u>22m/s</u>** (The same as the previous work)

q_b = **<u>0.3025KN/m^2</u>** (The same as the previous work)

<u>Step 2</u> Reference height: (Z_e)

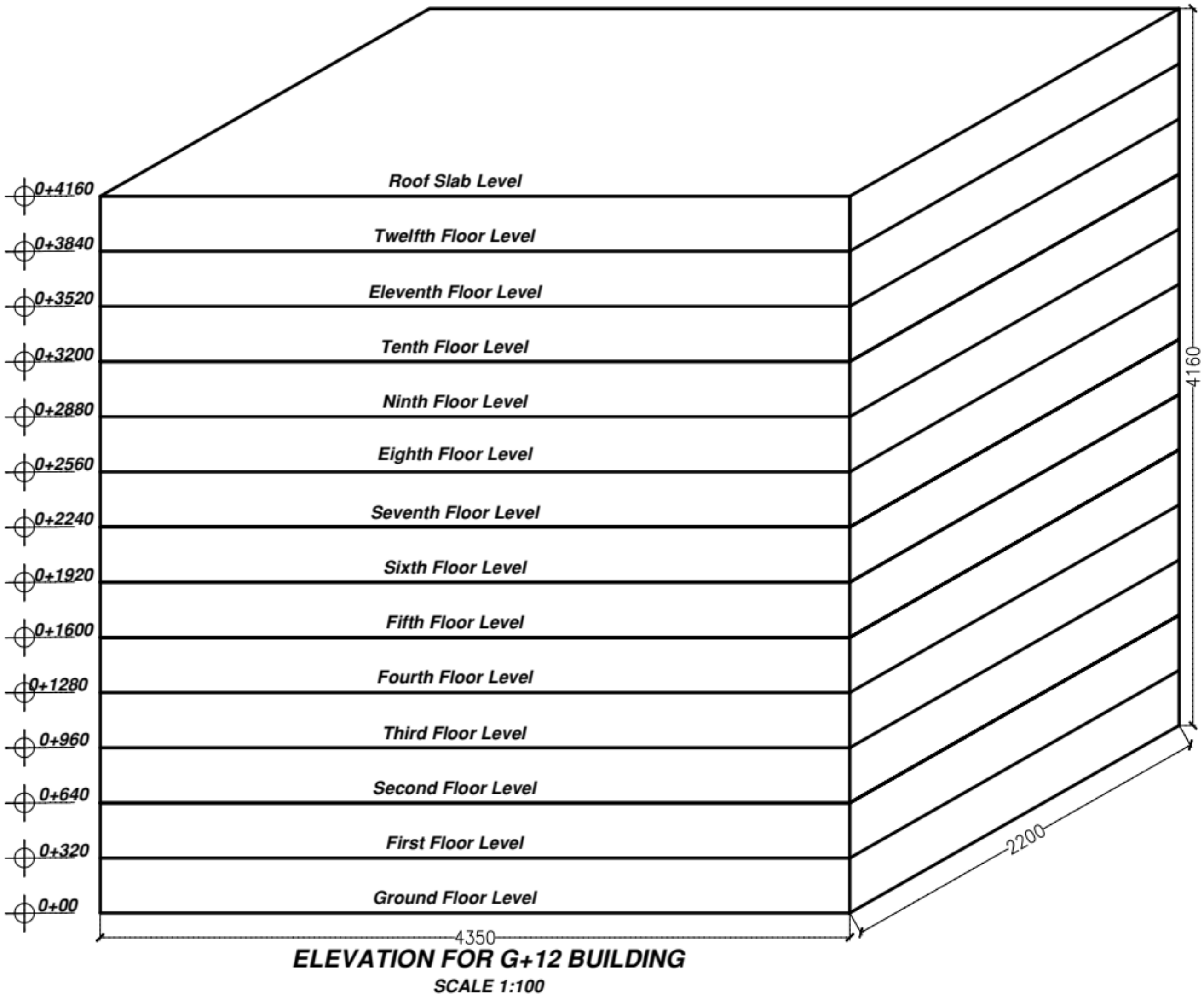


Figure C.13 Elevation of G+12 Building

Height of the building, h = 41.6m and b = 43.5m when the wind blows normal to X direction and b = 22m when the wind blow in Y direction. Thus, Z_e = h = 41.6m since, h < b when the wind blows normal to X direction and consider as one part and Z_e = b = 22m and Z_e = h = 41.6m since, b < h < 2b when the wind blows normal to Y direction and consider as two part.

<u>Step 3</u> Exposer coefficient: ($C_e(z)$)

Similarly as the previous work using figure 5.5, the exposer coefficient for terrain category II with reference of height of 41.6m and 22m is 3.35 and 2.84.

Thus, $C_e(z)$ = **<u>3.35</u>** for Z_e = h = **<u>41.6m</u>**

$C_e(z)$ = **<u>2.84</u>** for Z_e = b = **<u>22m</u>**

Step 4 **Characteristic peak velocity pressure :(q_p)**

q_p = 3.35*0.3025KN/m^2 = **1.013KN/m^2** for Z_e = 41.6m (when the wind blown normal to X direction)

q_p = 3.35*0.3025KN/m^2 = **1.013KN/m^2** for Z_e = 41.6m (when the wind blown normal to Y direction)

q_p = 2.84*0.3025KN/m^2 = **0.859KN/m^2** for Z_e = 22m (when the wind blown normal to Y direction)

Step 5 **Determine external pressure coefficient:** C_{pe} (z)

For wind blows normal to X direction (Longer wall)

e = min (b, 2h) = min (43.5, 2*41.6) = **43.5m**

d = 22m < e = 43.5m, thus the elevation for e > d according to figure 7.5 on ES EN 1: 2015 is;

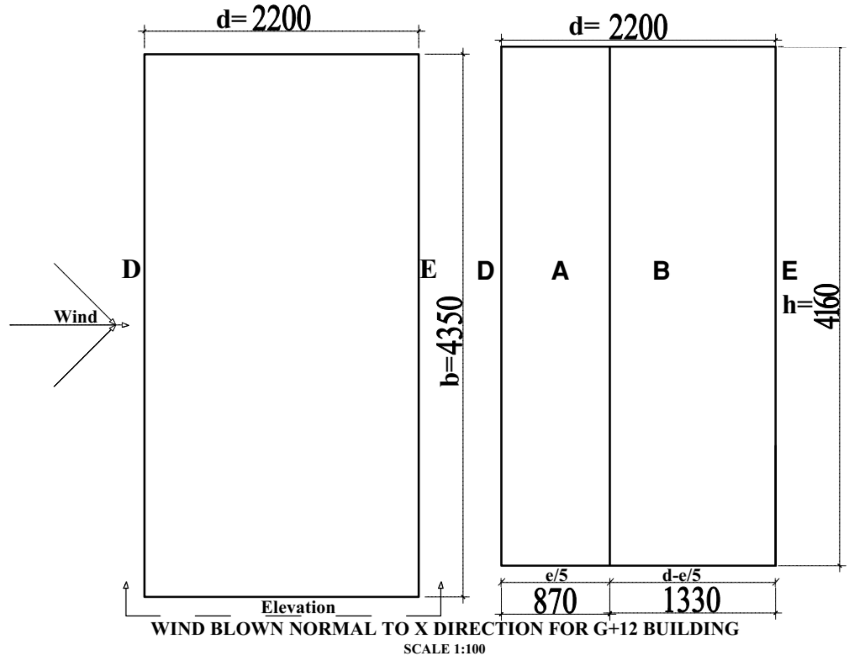


Figure C.14 Windblown normal to X direction for G+7 building

Area of wind regions and External pressure coefficient in x direction summary in the table shown below;
h/d = 41.6/22 = **1.89**

Table C.10 External pressure coefficient for wall normal to X direction for G+12 building

Zone	A	B	D	E
For Z_e = h = 41.6m and h/d = 1.89				
width (m)	8.7	13.3	43.5	43.5
Height (m)	41.6	41.6	41.6	41.6
Area (m^2)	361.92	553.28	1809.6	1809.6
C_{pe}	-1.2	-0.8	0.8	-0.58

For wind blows normal to Y direction (Shorter wall)

e = min (b, 2h) = min (22, 2*41.6) = **22m**

d = 43.5m > e = 22m, thus the elevation for d > e according to figure 7.5 on ES EN 1, 2015 is;

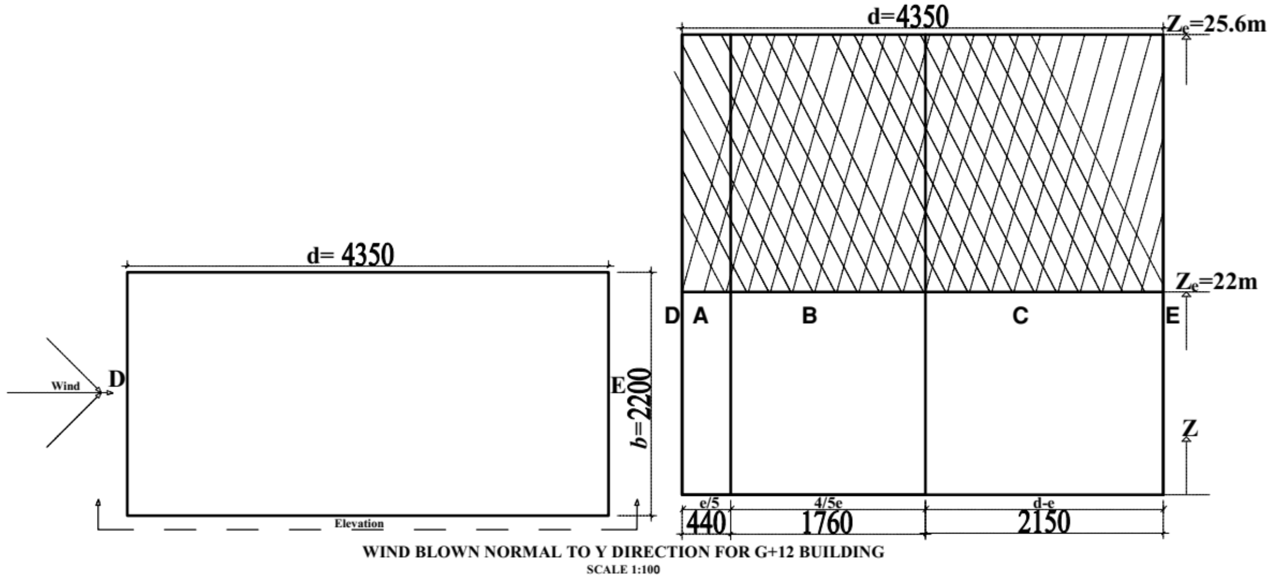


Figure C.15 Windblown normal to Y direction for G+12 building

Area of wind regions and External pressure coefficient in x direction summary in the table shown below; h/d = 22/43.5 = **<u>0.506</u>** for Z_e = 22m and h/d = 41.6/43.5 = **<u>0.96</u>** for Z_e = 41.6m

Table C.11 External pressure coefficient for wall normal to Y direction for G+7 building

Zone	A	B	C	D	E
For Z_e = b = 22m and h/d = 0.506					
width (m)	4.4	17.6	21.5	22	22
Height (m)	22	22	22	22	22
Area (m^2)	96.8	387.2	473	484	484
C_{pe}	-1.2	-0.8	-0.5	+0.78	-0.37
For Z_e = h = 41.6m and h/d = 096					
width (m)	4.4	17.6	21.5	22	22
Height (m)	41.6	41.6	41.6	41.6	41.6
Area (m^2)	96.8	387.2	473	484	484
C_{pe}	-1.2	-0.8	-0.5	+0.8	-0.5

<u>Step 6</u> Internal pressure coefficient:

Similarly as the previous work the extreme values internal pressure coefficient are +0.2 and -0.3.

Thus, C_{pi}^- = -0.3

C_{pi}^+ = +0.2

<u>Step 6</u> Net wind pressure:

Table C.12 Net pressure for G+12 building wall

Zone	Normal to X direction (Longer wall)					Normal to Y direction(Shorter wall)				
	A	B	C	D	E	A	B	C	D	E
C_{pe} (Z_e=41.6m)	-1.2	-0.8	-0.5	0.8	-0.58	-1.2	-0.8	-0.5	0.8	-0.5
C_{pe} (Z_e=22m)	-	-	-	-	-	-1.2	-0.8	-0.5	0.78	-0.37
C_{pi}^-	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30
C_{pi}^+	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
W_e (Z_e=41.6m)	-1.07	-0.72	-0.45	0.72	-0.52	-1.07	-0.72	-0.45	0.72	-0.45
W_e (Z_e=22m)	-	-	-	-	-	-1.03	-0.69	-0.43	0.67	-0.32
Wi^+ (Z_e=41.6m)	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Wi^+ (Z_e=22m)	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Wi^- (Z_e=41.6m)	-0.27	-0.27	-0.27	-0.27	-0.27	-0.27	-0.27	-0.27	-0.27	-0.27
Wi^- (Z_e=22m)	-0.26	-0.26	-0.26	-0.26	-0.26	-0.26	-0.26	-0.26	-0.26	-0.26
W_e-W_i^+ (Z_e=41.6m)	-1.25	-0.90	-0.63	0.54	-0.70	-1.25	-0.90	-0.63	0.54	-0.63
W_e-W_i^+ (Z_e=22m)	-	-	-	-	-	-1.21	-0.87	-0.61	0.49	-0.50
W_e-W_i^- (Z_e=41.6m)	-0.81	-0.45	-0.18	0.98	-0.25	-0.81	-0.45	-0.18	0.98	-0.18
W_e-W_i^- (Z_e=22m)	-	-	-	-	-	-0.77	-0.43	-0.17	0.93	-0.06

W_{net}^- (Z_e=41.6m) = **<u>-1.25 KN/m²</u>** (suction)

W_{net}^- (Z_e=22m) = **<u>-1.21 KN/m²</u>** (suction)

W_{net}^+ (Z_e=25.6m) = **<u>0.98KN/m²</u>** (pressure)

W_{net}^+ (Z_e=22m) = **<u>0.93KN/m²</u>** (pressure)

<u>Step 7</u>: Wind Force

Following similar procedure as the previous work for G+2 building, the wind forces for G+7 building computed as follow shown in the table below.

Table C.13 Wind forces for G+12 Building

Notation	Wind type	W (KN/m²)	h(m)	b(m)	A_{ref} (m²)	F_w (KN)	Remark
F_{w1}	suction	-1.25	3.20	3.75	12.00	-15.00	Z_e = 41.6m
F_{w2}	suction	-1.25	3.20	5.50	17.60	-22.00	
F_{w3}	suction	-1.25	3.20	5.75	18.40	-23.00	
F_{w4}	suction	-1.25	3.20	6.00	19.20	-24.00	
F_{w5}	pressure	0.93	3.20	4.00	12.80	11.90	Z_e = 22m
F_{w6}	pressure	0.93	3.20	6.00	19.20	17.86	
F_{w7}	pressure	0.98	3.20	4.00	12.80	12.54	Z_e = 41.6m
F_{w8}	pressure	0.98	3.20	6.00	19.20	18.82	

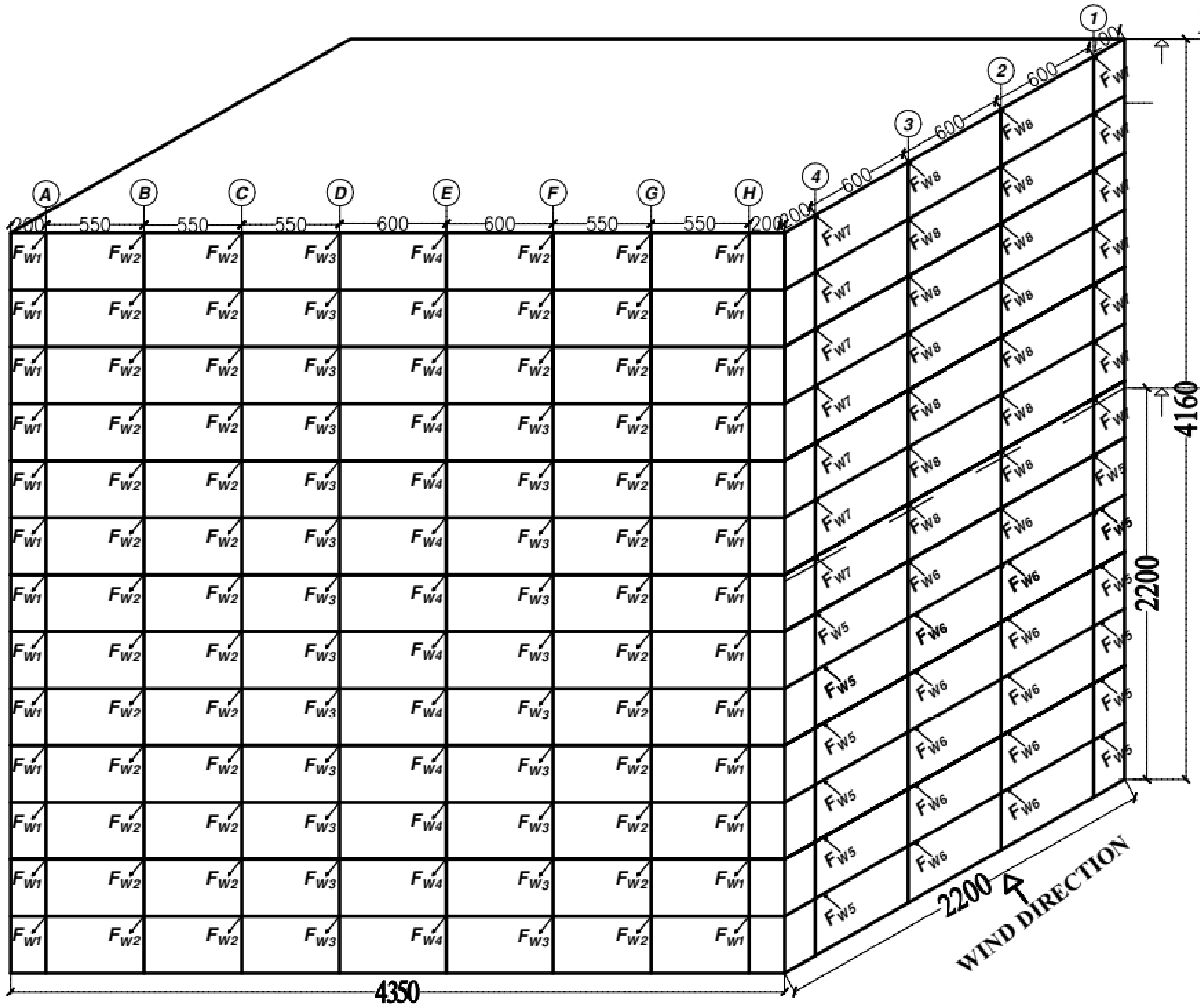


Figure C.16 Wind forces for G+12 Building

C.3.2 EARTHQUAKE LOAD ANALYSIS

According to section 4.3.3 on ES EN 8, there are four methods for analysis of seismic effect; “lateral force method of analysis”, “modal response spectrum analysis”, “Non-linear static (pushover) analysis” and “non-linear time history (dynamic)”. Among the four methods of earthquake load analysis, this research uses lateral force method of analysis because of the buildings response is not significantly affected by contributions from modes of vibration higher than the fundamental mode in each principal direction, it meets the criteria for regularity in elevation given in section 4.2.3.3 on ES EN 8: 2015 and the fundamental period of vibration is less than 2 seconds. Moreover modal response spectrum analysis method also used and the minimum value is taken for design. The buildings are located at Semera; which are propose for multipurpose use. The structure is reinforced concrete frame and assume the ground type of the site (Semera) is C which is deep deposits of dense or medium dense sand, gravel or stiff clay soil type and the structure is low ductile with type 2 of spectrum.

C.3.2.1 EARTHQUAKE LOAD ANALYSIS USING LATERAL FORCE METHOD

C.3.2.1.1 EARTHQUAKE LOAD ANALYSIS FOR G+2 BUILDING

The earthquake load analyzed using lateral force method of analysis as follow shown below.

<u>Step 1</u>: Determine fundamental period of vibration, T_1

For buildings with heights of up to 40 m the value of T_1 (in seconds) may be approximated by the following expression:

$T_1 = C_t \cdot H^{3/4}$ ………………………………………..……………………...Equation 4.6 ES EN 8: 2015

Where

C_t is 0.085 for moment resistant space steel frames, 0.075 for moment resistant space concrete frames and for eccentrically braced steel frames and 0.050 for all other structures;

H is the height of the building, in m, from the foundation or from the top of a rigid basement.

H = 1.5m + (3.2*3m) = **<u>11.1m</u>** (assuming the foundation is 1.5m below the ground level)

C_t = **<u>0.075</u>** (for moment resistant space concrete frames or reinforced concrete frame)

$T_1 = 0.075*11.1^{3/4}$ = **<u>0.456 Sec</u>**

<u>Step 2</u>: Determine design spectrum, $S_d(T)$

According to section 3.2.2.5 on ES EN 8: 2015, for the horizontal components of the seismic action the design spectrum, $S_d(T)$, shall be defined by the following expressions:

$$0 \le T \le T_B: \quad S_d(T) = a_g \cdot S \cdot \left[\frac{2}{3} + \frac{T}{T_B} \cdot \left(\frac{2.5}{q} - \frac{2}{3}\right)\right]$$ …………………………..Equation 3.13 ES EN 8: 2015

$$T_B \le T \le T_C: \quad S_d(T) = a_g \cdot S \cdot \eta \cdot \frac{2.5}{q}$$ ………………………………………..Equation 3.14 ES EN 8: 2015

$$T_C \le T \le T_D: \quad S_d(T) = \begin{cases} a_g . S . \frac{2.5}{q}\left[\frac{T_C}{T}\right] \\ \ge \beta . a_g \end{cases}$$ …………………….…………..…..Equation 3.15 ES EN 8: 2015

$$T_D \le T: \quad S_d(T) = \begin{cases} = a_g \cdot S \cdot \frac{2.5}{q} \cdot \left[\frac{T_C \cdot T_D}{T^2}\right] \\ \ge \beta \cdot a_g \end{cases}$$ ……………………………….………..Equation 3.16 ES EN 8: 2015

Where

$S_d(T)$ is the design spectrum;

a_g is the design ground acceleration;

T_B is the lower limit of the period of the constant spectral acceleration branch;

T_C is the upper limit of the period of the constant spectral acceleration branch;

T_D is the value defining the beginning of the constant displacement response range of the spectrum;

S is the soil factor;

q is the behaviour factor, Except as provided in section 10.10(5) on ES EN 8: 2015, the value of the behaviour factor shall be taken as being equal to q = 1. But in most literatures and educational examples, the value of behavioural factory is ranged from 3 to 6. Moreover, behavioural factor also computed using a formula, $q = q_o.K_w$, $q_o = 3\alpha_u/\alpha_1$ for low ductile frame, $\alpha_u/\alpha_1 = 1.3$ and $K_w = 1$. Accordingly, q = 3*1.3*1 = 3.9. Let us take behavioural factors as 4.

β is the lower bound factor for the horizontal design spectrum. The recommended value for β is 0.2.

η is the damping correction factor with a reference value of $\eta = 1$ for 5% viscous damping, or;

$\eta = \sqrt{10/(5+\xi)} \geq 0.55$ ………………………………………...……....Equation 3.6 ES EN 8: 2015

Where

ξ is the viscous damping ratio of the structure, expressed as a percentage. If for special cases a viscous damping ratio different from 5% is to be used, this value is given in the relevant Part of ES EN 1998

According to table 3.3 on ES EN 8: 2015 the value of the parameters (S, T_B, T_C, T_D) for ground type C with type 1 elastic response spectra are;

S = **1.15** T_B = **0.2 Sec** T_C = **0.6 Sec** T_D = **2 Sec**

The design ground acceleration is computed by using the expression: $a_g = \alpha_0 \cdot g . \gamma_I$

Where

γ_I is importance factor;

g is acceleration of gravity which equals to 9.81 m/s^2

α_0 is the bed rock acceleration ratio. The value of $\alpha_0 = a_g/g$ is given on table D1 on ES EN 8: 2015 for importance factor equals to 1.

For a building with multipurpose use, the importance category or importance class is II (Ordinary buildings, not belonging in the other categories); the value of γ_I equal to 1.0.

According to table D2 on ES EN 8: 2015, seismic hazard zonation for selected towns of Ethiopian Semera is under seismic zone 5. Thus, the value of $a_o = 0.2$.

$a_g = 0.2*9.81*1 =$ **1.962 m/sec²**

$S_d(T_1) = a_g.S.\ \eta.\frac{2.5}{q}$ ………..For $T_B \leq T_1 \leq T_C$

$S_d(0.456) = 1.962*1.15*1*\frac{2.5}{4}$ = **1.41 m/sec²**

Step 3: **Determine total mass of the building, m**

The total mass of the building is the same of dead load with some percentage of live load. The inertial effects of the design seismic action shall be evaluated by taking into account the presence of the masses associated with all gravity loads appearing in the following combination of actions:

W = $\sum G_{k,j}$ "+" $\sum \psi_{E,i} \cdot Q_{k,i}$ …………………………………………...Equation 3.17 ES EN 8: 2015

Where

G_k is dead load;

Q_k is live load;

W is weight of combined actions;

ψ_{Ei} is the combination coefficient for variable action in the building.

The combination coefficients ψ_{Ei} for the calculation of the effects of the seismic actions shall be computed from the following expression:

$\psi_{Ei} = \varphi.\psi_{2i}$ ……………………………………………………………...Equation 4.2 ES EN 8: 2015

Where

φ is load type coefficient;

ψ_{2i} is the combination coefficients for the quasi-permanent value of variable action q_i

The values for φ for variable action category D-F base on table 4.2 on ES EN 8: 2015 is 1. According to table A1.1 on ES EN 0:2015, the values of ψ_2 is 0.3 for action category A (Domestic area) and B(Office), 0.6 for action category C (Congested area) and D(shop) and 0 for action category H (roof). Since the building is multipurpose building and has many functionality take ψ_2 as 0.3 for all floors and 0 for roof.

ψ_{Ei} = 1*0.3 = **0.3** for floors ψ_{Ei} = 1*0 = **0** for roof

Step 3.1: **Determine total mass of the building with C-25 concrete, m**

Step 3.1.1 Determine floor dead load, G_k

The dead weight of the building is the sum of self-weight of column, beam, slab, staircase, partition wall and other permanent loads. The total mass of the building is the same of dead load and some percentage of live load at each floor. For analysis and computation of dead load for beam, column, slab and staircase the following structural element trial dimension is assumed as shown below.

Table C.14 Assumed trial section of G+2 building for C-25 concrete

Location	Structural Element Dimension (cm)			
	Beam	**column**	**slab**	**staircase**
Under ground floor	-	Ø30	-	-
Ground floor	25x40	Ø30	-	25 cm thick
First & Second floor	25x40	Ø30	15 cm thick	25 cm thick
Roof	25x30	-	15 cm thick	-

The seismic dead load for each floor computed as shown in the table below.

Table C.15 Dead load for G+2 building with C-25 concrete

Element	No	Member	L (m)	b (m)	t (m)	γ (KN/m^3)	G_k (KN)
Under Ground Floor							
Foundation column	30	1	1.1	0.3	0.3	25	58.29
Sub Total (1)							**58.29**
Ground Floor							
Aluminum Wall (4mm)	1	1	122.75	3.05	0.004	27	40.43
HCB Wall (20cm)	1	1	58.4	3.05	0.2	14	498.74
HCB Wall (10cm)	1	1	104.5	3.05	0.1	14	446.22
HCB Wall Plaster (20cm)	2	1	58.4	3.05	0.03	23	245.81
HCB Wall plaster(10cm)	2	1	104.5	3.05	0.03	23	439.84
Beam on axis 2 & 3	2	1	39.5	0.25	0.4	25	197.50
Beam on axis 1 & 4	2	1	31	0.25	0.4	25	155.00
Curved beam	1	1	28.75	0.25	0.4	25	71.88
Beam on axis B-H	7	1	18	0.25	0.4	25	315.00
Column	30	1	2.85	0.3	0.3	25	151.01
Column plaster	30	1	2.85	0.942	0.03	23	55.57
Landing Beam	1	1	6	0.25	0.4	25	15.00
Landing beam plaster	1	1	6	0.75	0.03	23	3.11
Staircase waist	2	1	3	1.5	0.25	25	56.25
Staircase Landing	2	1	6	1.6	0.15	25	72.00
Staircase Landing plaster	2	1	6	1.6	0.03	23	13.25
Staircase waist plaster	2	1	3	1.5	0.03	23	6.21
Sub Total (2)							**2782.81**
First and Second Floor							
Slab (Rectangular)	1	2	33	22	0.15	25	5445.00
Slab (Circular)	1	2	186.83		0.15	25	1401.23
Slab plaster (Rectangular)	1	2	33	22	0.03	23	1001.88
Slab plaster (Circular)	1	2	186.83		0.03	23	257.83
Cement screed (Rectangular)	1	2	33	22	0.03	23	1001.88
Cement screed (Circular)	1	2	186.83		0.03	23	257.83
Floor finish (Rectangular)	1	2	33	22	0.02	27	784.08
Floor finish (Circular)	1	2	186.83		0.02	27	201.78
Aluminum Wall (4mm)	1	2	122.75	3.05	0.004	27	80.87
HCB Wall (20cm)	1	2	58.4	3.05	0.2	14	997.47
HCB Wall (10cm)	1	2	104.5	3.05	0.1	14	892.43
HCB Wall Plaster (20cm)	2	2	58.4	3.05	0.03	23	491.61
HCB Wall plaster(10cm)	2	2	104.5	3.05	0.03	23	879.68

Element	No	Member	L (m)	b (m)	t (m)	γ (KN/m^3)	G_k (KN)
Beam on axis 2 & 3	2	2	39.5	0.25	0.4	25	395.00
Beam on axis 1 & 4	2	2	31	0.25	0.4	25	310.00
Curved beam	1	2	28.75	0.25	0.4	25	143.75
Beam on axis B-H	7	2	18	0.25	0.4	25	630.00
Beam plaster on axis 2 & 3	2	2	39.5	0.75	0.03	25	88.88
Beam plaster on axis 1 & 4	2	2	31	0.75	0.03	25	69.75
Curved plaster beam	1	2	28.75	0.75	0.03	25	32.34
Beam plaster on axis B-H	7	2	18	0.75	0.03	25	141.75
Column	30	2	2.85	0.3	0.3	25	302.03
Column plaster	30	2	2.85	0.942	0.03	23	111.15
Landing Beam	1	2	6	0.25	0.4	25	30.00
Landing beam plaster	1	2	6	0.75	0.03	25	6.75
Staircase Landing	2	2	3	1.5	0.25	25	112.50
Staircase waist	2	2	5.5	1.6	0.25	25	220.00
Staircase Landing plaster	2	2	3	1.5	0.03	23	12.42
Staircase waist plaster	2	2	5.5	1.6	0.03	23	24.29
Sub Total (3)							**16324.16**
Roof							
Beam on axis 2 & 3	2	2	39.5	0.25	0.3	25	296.25
Beam on axis 1 & 4	2	2	31	0.25	0.3	25	232.50
Curved beam	1	2	28.75	0.25	0.3	25	107.81
Beam on axis B-H	7	2	18	0.25	0.3	25	472.50
Beam plaster on axis 2 & 3	2	2	39.5	0.55	0.03	25	65.18
Beam plaster on axis 1 & 4	2	2	31	0.55	0.03	25	51.15
Curved plaster beam	1	2	28.75	0.55	0.03	25	23.72
Beam plaster on axis B-H	7	2	18	0.55	0.03	25	103.95
Concrete roof (Rectangular)	1	1	33	22	0.15	25	2722.50
Concrete roof (Circular)	1	1	186.83		0.15	25	700.61
Concrete roof plaster (Rectangular)	1	1	33	22	0.03	23	500.94
Concrete roof plaster (Circular)	1	1	186.83		0.03	23	128.91
Parapet wall	1	1	109.04	1	0.2	14	305.31
Light weigh concrete (Rectangular)	1	1	33	22	0.06	14	609.84
Light weigh concrete (Circular)	1	1	186.83		0.06	14	156.94
Waterproof (Rectangular)	1	1	33	22	0.004	16	46.46
Waterproof (Circular)	1	1	186.83		0.004	16	11.96
Sub Total (4)							**6536.53**

Step 3.1.2 Determine floor live load, Q_k

The live load is computed based on the building functional rooms; the building is proposed for multipurpose such as for hotel, office, toilet, kitchens, cinema hall, conference and assembly hall, shop, stores, stairs, balconies and the like. The live load of different buildings is taken from ES EN 1: 2015, part 1-1. According to table 6.2, live load range from 1.5 to 7.5 KN/m^2. Considering the building gives multipurpose a medium value of live load is taken as 3 KN/m^2 for structural analysis and design of G+2, 7 & 12 buildings. Moreover, according to table 6.9, the value of live load for roof not accessible except for normal maintenance and repair (loaded area category H) is 0.4 KN/m^2.

The concentrated live load, Q_k is computed by multiplying the areal live load, q_k with the area of the building, A. $Q_k = q_k.A$

<u>Step 3.1.3</u> Determine total mass, m

The total mass of the building is computed by dividing the weight of the combined actions in equation 3.17 by gravitational acceleration; $m = \frac{W}{g}$. Accordingly, the total mass for G+2 building with C-25 concrete computed as follow shown in the table below.

Table C.16 Total mass for G+2 building with C-25 concrete

Story	Area (m^2)	q_k (KN/m^2)	Q_k (KN)	G_k(KN)	ψ_{Ei}	W (KN)	m (Ton)
Roof	912.83	0.40	365.13	6536.53	0.00	6536.53	666.31
Second floor	912.83	3.00	2738.49	8162.08	0.30	8983.63	915.76
First floor	912.83	3.00	2738.49	8162.08	0.30	8983.63	915.76
Ground floor				2782.81		2782.81	283.67
Under ground floor				58.29		58.29	5.94
Total mass							**<u>2787.45</u>**

<u>Step 3.2</u>: Determine total mass of the building with C-40 concrete, m

<u>Step 3.2.1</u> Determine floor dead load, G_k

Table C.17 Assumed trial section of G+2 building for C-40 concrete

Location	Structural Element Dimension (cm)			
	Beam	**Column**	**Slab**	**Staircase**
Under ground floor	-	Ø25	-	-
Ground floor	20x35	Ø25	-	21 cm thick
First & Second floor	20x35	Ø25	15 cm thick	21 cm thick
Roof	20x30	-	15 cm thick	-

Following similar procedure as dead load calculation for G+2 building with C-25 concrete, the dead load of G+2 building with C-40 concrete is given in the table shown below.

Table C.18 Dead load for G+2 building with C-40 concrete

Floor	Total dead load, G_k (KN)
Under Ground Floor	40.48
Ground Floor	2505.59
First and Second Floor	15641.26
Roof	6239.96

<u>Step 3.2.2</u> Determine floor live load, Q_k

The same as the above value. i.e $q_k = 3\ KN/m^3$ for functional room and $q_k = 0.4\ KN/m^3$ for roof.

<u>Step 3.2.3</u> Determine total mass, m

Table C.19 Total mass for G+2 building with C-40 concrete

Story	Area (m^2)	q_k (KN/m^2)	Q_k (KN)	G_k(KN)	ψ_{Ei}	W (KN)	m (Ton)
Roof	912.83	0.40	365.13	6239.96	0.00	6239.96	636.08
Second floor	912.83	3.00	2738.49	7820.63	0.30	8642.18	880.96
First floor	912.83	3.00	2738.49	7820.63	0.30	8642.18	880.96
Ground floor				2505.59		2505.59	255.41
Under ground floor				40.48		40.48	4.13
Total mass							**<u>2657.53</u>**

<u>Step 4</u>: Determine Base shear, F_b

$F_b = S_d (T_1) \cdot m \cdot \lambda$……………..…………………………………………...Equation 4.5 ES EN 8: 2015

where

$S_d (T_1)$ is the ordinate of the design spectrum at period T_1;

T_1 is the fundamental period of vibration of the building;

m is the total mass of the building, above the foundation or above the top of a rigid basement,

λ is the correction factor, the value of which is equal to: $\lambda = 0.85$ if $T_1 \leq 2\ T_c$ and the building has more than two storeys, or $\lambda = 1.0$ otherwise.

<u>Step 4.1</u>: Determine Base shear for building with C-25 concrete

$S_d (T_1) = 1.41\ m/s^2$ m = 2787.45 Ton $\lambda = 0.85$

$F_b = 1.41\ m/s^2 * 2787.45\ t * 0.85 =$ **<u>3340.75 KN</u>**

<u>Step 4.2</u>: Determine Base shear for building with C-40 concrete

$S_d (T_1) = 1.41\ m/s^2$ m = 2657.53 t $\lambda = 0.85$

$F_b = 1.41\ m/s^2 * 2657.53\ t * 0.85 =$ **<u>3185.05KN</u>**

<u>Step 5</u>: Distribution of base shear, F_i

According to section 4.3.3.2.3 on ES EN 8: 2105, the base shear can be distributed to the corresponding floors as horizontal forces F_i considering fundamental mode shape is approximated by horizontal displacements increasing linearly along the height using the formula given below.

$$F_i = F_b \cdot \frac{z_i \cdot m_i}{\sum z_j \cdot m_j}$$ ………………………………………………...…...Equation 4.11 ES EN 8: 2015

where

z_i, z_j are the heights of the masses m_i, m_j above the level of application of the seismic action

<u>Step 5.1</u>: Distribution of base shear for building with C-25 concrete

Table C.20 Distribution of base shear for G+2 building with C-25 concrete

Story	Z_i (m)	m (ton)	$Z_i.m_i$ (m.ton)	F_b (KN)	F_i (KN)
Roof	11.10	666.31	7396.08	3340.75	1276.25
Second floor	7.90	915.76	7234.52	3340.75	1248.37
First floor	4.70	915.76	4304.08	3340.75	742.70
Ground floor	1.50	283.67	425.51	3340.75	73.42
Total			19360.18		

<u>Step 5.2</u>: Distribution of base shear for building with C-40 concrete

Table C.21 Distribution of base shear for G+2 building with C-40 concrete

Story	Z_i (m)	m (ton)	$Z_i.m_i$ (m.ton)	F_b (KN)	F_i (KN)
Roof	11.10	636.08	7060.50	3185.05	1161.56
Second floor	7.90	880.96	6959.55	3185.05	1144.95
First floor	4.70	880.96	4140.49	3185.05	681.18
Ground floor	1.50	255.41	383.12	3185.05	63.03
Total			18543.66		

<u>Step 6</u>: Determine point of center of mass,(X_m, Y_m)

The center of mass is the point where the mass is concentrated or the point where the story shear for each floor is applied. The center of mass in the building is calculated for slab, wall, beam and column. The center of mass for each structural element is calculated as given by;

$$X_m = \sum W_i X_i / \sum W_i \qquad Y_m = \sum W_i Y_i / \sum W_i$$

Where

W_i is the dead load of the corresponding mass;

X_i & Y_i are center of the corresponding mass in X direction & Y direction respectively;

X_m & Y_m are center of the building at each floor in X direction & Y direction respectively.

<u>Remark 5.1</u> - Since the building is regular and there is no as such offset or uneven distribution of the center of mass is takes as equal with geometric center of the building or the software itself can apply center of mass of the building as a diaphragm center of mass. For this research center of mass apply at diaphragm center by checking apply load at diaphragm center of mass option using the software itself.

C.3.2.1.2 EARTHQUAKE LOAD ANALYSIS FOR G+7 BUILDING

<u>Step 1</u>: Determine fundamental period of vibration, T_1

H = 3m + (3.2*8m) = **<u>28.6m</u>** (assuming the foundation is 3m below the ground level)

C_t = **<u>0.075</u>** (for moment resistant space concrete frames or reinforced concrete frame)

$T_1 = 0.075*28.6^{3/4}$ = **<u>0.928 Sec</u>**

<u>Step 2</u>: Determine design spectrum, $S_d(T)$

Using equation 3.15, the design spectrum is computed as follow;

S = 1.15 T_B = 0.2 Sec T_C = 0.6 Sec T_1 = 0.928 Sec T_D = 2 Sec $a_g = 1.962\ m/s^2$ β = 0.2 q = 1

$$S_d(T_1) = \begin{cases} a_g.S.\frac{2.5}{q}\left[\frac{T_C}{T_1}\right] \\ \geq \beta.a_g \end{cases} \quad \ldots\ldots \text{ for } T_C \leq T_1 \leq T_D$$

$$S_d(0.928) = \begin{cases} 1.962 * 1.15 * \frac{2.5}{4}\left[\frac{0.6}{0.928}\right] \\ \geq 0.2 * 1.962 = 0.392\ m/s^2 \end{cases} = 0.912\ m/s^2$$

$S_d(0.928)$ = **<u>0.912 m/s²</u>**

<u>Step 3</u>: Determine total mass of the building, m

<u>Step 3.1</u>: Determine total mass of the building with C-25 concrete

<u>Step 3.1.1</u> Determine floor dead load, G_k

Table C.22 Assumed trial section of G+7 building for C-25 concrete

Location	Structural Element Dimension (cm)			
	Beam	column	slab	staircase
Under ground floor	-	Ø60	-	-
Ground floor	30x45	Ø60	-	25 cm thick
First & Second floor	30x45	Ø60	17 cm thick	25 cm thick
$3^{rd} – 5^{th}$ floor	30x40	Ø50	17 cm thick	25 cm thick
6^{th}-7^{th} floor	25x40	Ø40	17 cm thick	25 cm thick
Roof	25x30	-	17 cm thick	-

Following similar procedure as dead load calculation for G+2 building with C-25 concrete, the dead load of G+7 with C-25 concrete is given in the table shown below.

Table C.23 Dead load for G+7 building with C-25 concrete

Floor	Total dead load, G_k (KN)
Under Ground Floor	540.47
Ground Floor	3523.59
First and Second Floor	18677.72
3^{rd}-5^{th} Floor	27056.35
6^{th}-7^{th} Floor	17398.53
Roof	6922.62

<u>Step 3.1.2</u> Determine floor live load, Q_k

The same as the above. i.e $q_k = 3\ KN/m^3$ for functional room and $q_k = 0.4\ KN/m^3$ for roof.

Step 3.1.3 Determine total mass, m

Table C.24 Total mass for G+7 building with C-25 concrete

Story	Area (m^2)	q_k (KN/m^2)	Q_k (KN)	G_k(KN)	ψ_{Ei}	W (KN)	m (Kg)
Roof	912.83	0.40	365.13	6922.62		6922.62	705.67
Roof	912.83	3.00	2738.49	8699.26	0.30	9520.81	970.52
7th Floor	912.83	3.00	2738.49	8699.26	0.30	9520.81	970.52
6th Floor	912.83	3.00	2738.49	9018.78	0.30	9840.33	1003.09
5th Floor	912.83	3.00	2738.49	9018.78	0.30	9840.33	1003.09
4th Floor	912.83	3.00	2738.49	9018.78	0.30	9840.33	1003.09
3rd Floor	912.83	3.00	2738.49	9338.86	0.30	10160.40	1035.72
First floor	912.83	3.00	2738.49	9338.86	0.30	10160.40	1035.72
Ground floor			0.00	3523.59		3523.59	359.18
Under ground floor			0.00	540.47		540.47	55.09
Total mass							**8141.70**

Step 3.2: **Determine total mass of the building with C-40 concrete, m**

Step 3.2.1 Determine floor dead load, G_k

Table C.25 Assumed trial section of G+7 building for C-40 concrete

Location	Structural Element Dimension (cm)			
	Beam	column	slab	staircase
Under ground floor	-	Ø50	-	-
Ground floor	30x40	Ø50	-	21 cm thick
First & Second floor	30x40	Ø50	15 cm thick	21 cm thick
3rd – 5th floor	25x40	Ø40	15 cm thick	21 cm thick
6th-7th floor	25x35	Ø30	15 cm thick	21 cm thick
Roof	20x30	-	15 cm thick	-

Following similar procedure as dead load calculation for G+2 building with C-25 concrete, the dead load of G+7 building with C-40 concrete is given in the table shown below.

Table C.26 Dead load for G+7 building with C-40 concrete

Floor	Total dead load, G_k (KN)
Under Ground Floor	382.69
Ground Floor	3207.04
First and Second Floor	17089.14
3rd-5th Floor	24657.11
6th-7th Floor	15948.93
Roof	6239.96

Step 3.2.2 Determine floor live load, Q_k

The same as the above value. i.e q_k = 3 KN/m^3 for functional room and q_k = 0.4 KN/m^3 for roof.

Step 3.2.3 **Determine total mass, m**

Table C.27 Total mass for G+7 building with C-40 concrete

Story	Area (m^2)	q_k (KN/m^2)	Q_k (KN)	G_k(KN)	ψ_{Ei}	W (KN)	m (Kg)
Roof	912.83	0.40	365.13	6239.96	0.00	6239.96	636.08
7th Floor	912.83	3.00	2738.49	7974.46	0.30	8796.01	896.64
6th Floor	912.83	3.00	2738.49	7974.46	0.30	8796.01	896.64
5th Floor	912.83	3.00	2738.49	8219.04	0.30	9040.59	921.57
4th Floor	912.83	3.00	2738.49	8219.04	0.30	9040.59	921.57
3rd Floor	912.83	3.00	2738.49	8219.04	0.30	9040.59	921.57
Second floor	912.83	3.00	2738.49	8544.57	0.30	9366.12	954.75
First floor	912.83	3.00	2738.49	8544.57	0.30	9366.12	954.75
Ground floor			0.00	3207.09		3207.09	326.92
Under ground floor			0.00	382.69		382.69	39.01
Total mass							**7469.50**

Step 4: **Determine Base shear, F_b**

Step 4.1: **Determine Base shear for building with C-25 concrete**

$S_d(T_1) = 0.912\ m/s^2$ $\qquad$ $m = 8141.70$ t $\qquad$ $\lambda = 1$

$F_b = 0.912\ m/s^2 * 8141.70\ t * 1 =$ **7425.2 KN**

Step 4.2: **Determine Base shear for building with C-40 concrete**

$S_d(T_1) = 0.912\ m/s^2$ $\qquad$ $m = 7469.50$ t $\qquad$ $\lambda = 1$

$F_b = 0.912\ m/s^2 * 7469.50\ t * 1 =$ **6812.18 KN**

Step 5: **Distribution of base shear, F_i**

Step 5.1: **Distribution of base shear for building with C-25 concrete**

Table C.28 Distribution of base shear for G+7 building with C-25 concrete

Story	Z_i (m)	m (ton)	$Z_i.m_i$ (m.ton)	F_b (KN)	F_i (KN)
Roof	28.60	705.67	20182.16	7425.20	1142.55
7th Floor	25.40	970.52	24651.23	7425.20	1395.55
6th Floor	22.20	970.52	21545.56	7425.20	1219.73
5th Floor	19.00	1003.09	19058.74	7425.20	1078.95
4th Floor	15.80	1003.09	15848.85	7425.20	897.23
3rd Floor	12.60	1003.09	12638.96	7425.20	715.51
Second floor	9.40	1035.72	9735.76	7425.20	551.16
First floor	6.20	1035.72	6421.46	7425.20	363.53
Ground floor	3.00	359.18	1077.55	7425.20	61.00
Total			131160.27		

Step 5.2: **Distribution of base shear for building with C-40 concrete**

Table C.29 Distribution of base shear for G+7 building with C-40 concrete

Story	Z_i (m)	m (ton)	$Z_i.m_i$ (m.ton)	F_b (KN)	F_i (KN)
Roof	28.60	636.08	18191.93	6812.18	944.85
7th Floor	25.40	896.64	22774.59	6812.18	1182.86
6th Floor	22.20	896.64	19905.35	6812.18	1033.84
5th Floor	19.00	921.57	17509.80	6812.18	909.42
4th Floor	15.80	921.57	14560.78	6812.18	756.26
3rd Floor	12.60	921.57	11611.76	6812.18	603.09
Second floor	9.40	954.75	8974.67	6812.18	466.12
First floor	6.20	954.75	5919.46	6812.18	307.44
Ground floor	3.00	326.92	980.76	6812.18	50.94
Total			120429.09		

Step 6: **Determine point of center of mass,(X_m, Y_m)**

The same as the above value. (i.e the load apply at diaphragm center of mass)

C.3.2.1.3 EARTHQUAKE LOAD ANALYSIS FOR G+12 BUILDING

Step 1: **Determine fundamental period of vibration, T_1**

H = 3m + (3.2*13m) = **44.6m** (assuming the foundation is 3m below the ground level)

C_t = **0.075** (for moment resistant space concrete frames or reinforced concrete frame)

$T_1 = 0.075*44.6^{3/4}$ = **1.294 Sec**

Step 2: **Determine design spectrum, S_d(T)**

Using equation 3.15, the design spectrum is computed as follow;

S = 1.15 T_B = 0.2 Sec T_C = 0.6 Sec T_1 = 1.294 Sec T_D = 2 Sec $a_g = 1.962\ m/s^2$ $\beta = 0.2$ q = 1

$$S_d(T_1) = \begin{cases} a_g.S.\frac{2.5}{q}\left[\frac{T_C}{T_1}\right] \\ \geq \beta.a_g \end{cases} \quad \ldots\ldots \text{ for } T_C \leq T_1 \leq T_D$$

$$S_d(1.294) = \begin{cases} 1.962 * 1.15 * \frac{2.5}{4}\left[\frac{0.6}{1.294}\right] \\ \geq 0.2 * 1.962 = 0.392\ m/s^2 \end{cases} = 0.654\ m/s^2$$

S_d (0.928) = **$0.654\ m/s^2$**

Step 3: **Determine total mass of the building, m**

Step 3.1: **Determine total mass of the building with C-25 concrete**

Step 3.1.1 Determine floor dead load, G_k

Table C.30 Assumed trial section of G+12 building for C-25 concrete

Location	Structural Element Dimension (cm)			
	Beam	column	slab	staircase
Under ground floor	-	Ø80	-	-
Ground floor	35x55	Ø80	-	25 cm thick
First & Second floor	35x55	Ø80	20 cm thick	25 cm thick
3rd –5th floor	30x50	Ø70	20 cm thick	25 cm thick
6th-8th floor	30x45	Ø60	20 cm thick	25 cm thick
9th-10th floor	30x40	Ø50	20 cm thick	25 cm thick
11th-12th floor	25x40	Ø40	20 cm thick	25 cm thick
Roof	25x35	-	20 cm thick	-

Following similar procedure as dead load calculation for G+2 building with C-25 concrete, the dead load of G+12 building with C-25 concrete is given in the table shown below.

Table C.31 Dead load for G+12 building with C-25 concrete

Floor	Total dead load, G_k (KN)
Under Ground Floor	923.16
Ground Floor	4392.65
First and Second Floor	21844.75
3rd-5th Floor	31054.22
6th-8th Floor	30095.28
9th-10th Floor	19391.15
11th-12th Floor	18734.14
Roof	7809.83

Step 3.1.2 Determine floor live load, Q_k

The same as the above. i.e q_k = 3 KN/m^3 for functional room and q_k = 0.4 KN/m^3 for roof.

Step 3.1.3 Determine total mass, m

Table C.32 Total mass for G+12 building with C-25 concrete

Story	Area (m^2)	q_k (KN/m^2)	Q_k (KN)	G_k(KN)	ψ_{Ei}	W (KN)	m (Kg)
Roof	912.83	0.40	365.13	7809.83	0.00	7809.83	796.11
12th Floor	912.83	3.00	2738.49	9367.07	0.30	10188.62	1038.60
11th Floor	912.83	3.00	2738.49	9367.07	0.30	10188.62	1038.60
10th Floor	912.83	3.00	2738.49	9695.57	0.30	10517.12	1072.08
9th Floor	912.83	3.00	2738.49	9695.57	0.30	10517.12	1072.08

Story	Area (m^2)	q_k (KN/m^2)	Q_k (KN)	G_k(KN)	ψ_{Ei}	W (KN)	m (Kg)
8th Floor	912.83	3.00	2738.49	10031.76	0.30	10853.31	1106.35
7th Floor	912.83	3.00	2738.49	10031.76	0.30	10853.31	1106.35
6th Floor	912.83	3.00	2738.49	10031.76	0.30	10853.31	1106.35
5th Floor	912.83	3.00	2738.49	10351.41	0.30	11172.95	1138.94
4th Floor	912.83	3.00	2738.49	10351.41	0.30	11172.95	1138.94
3rd Floor	912.83	3.00	2738.49	10351.41	0.30	11172.95	1138.94
Second floor	912.83	3.00	2738.49	10922.37	0.30	11743.92	1197.14
First floor	912.83	3.00	2738.49	10922.37	0.30	11743.92	1197.14
Ground floor			0.00	4392.65		4392.65	447.77
Under ground floor			0.00	923.16		923.16	94.10
Total mass							**14689.47**

Step 3.2: Determine total mass of the building with C-40 concrete, m

Step 3.2.1 Determine floor dead load, G_k

Table C.33 Assumed trial section of G+12 building for C-40 concrete

Location	Structural Element Dimension (cm)			
	Beam	**column**	**slab**	**staircase**
Under ground floor	-	Ø70	-	-
Ground floor	30x50	Ø70	-	21 cm thick
First & Second floor	30x50	Ø70	15 cm thick	21 cm thick
3rd –5th floor	30x45	Ø60	15 cm thick	21 cm thick
6th-8th floor	30x40	Ø50	15 cm thick	21 cm thick
9th-10th floor	25x40	Ø40	15 cm thick	21 cm thick
11th-12th floor	25x35	Ø30	15 cm thick	21cm thick
Roof	20x30	-	15 cm thick	-

Following similar procedure as dead load calculation for G+2 building with C-25 concrete, the dead load of G+12 building with C-40 concrete is given in the table shown below.

Table C.34 Dead load for G+12 building with C-40 concrete

Floor	Total dead load, G_k (KN)
Under Ground Floor	721.22
Ground Floor	3868.61
First and Second Floor	18354.24
3rd-5th Floor	26497.13
6th-8th Floor	25563.86
9th-10th Floor	16385.57
11th-12th Floor	15884.40
Roof	6195.60

Step 3.2.2 Determine floor live load, Q_k

The same as the above value. i.e q_k = 3 KN/m^3 for functional room and q_k = 0.4 KN/m^3 for roof.

Step 3.2.3 Determine total mass, m

Table C.35 Total mass for G+12 building with C-40 concrete

Story	Area (m^2)	q_k (KN/m^2)	Q_k (KN)	G_k(KN)	ψ_{Ei}	W (KN)	m (Kg)
Roof	912.83	0.40	365.13	6195.60	0.00	6195.60	631.56
12th Floor	912.83	3.00	2738.49	7942.20	0.30	8763.75	893.35
11th Floor	912.83	3.00	2738.49	7942.20	0.30	8763.75	893.35
10th Floor	912.83	3.00	2738.49	8192.78	0.30	9014.33	918.89
9th Floor	912.83	3.00	2738.49	8192.78	0.30	9014.33	918.89
8th Floor	912.83	3.00	2738.49	8521.29	0.30	9342.83	952.38
7th Floor	912.83	3.00	2738.49	8521.29	0.30	9342.83	952.38
6th Floor	912.83	3.00	2738.49	8521.29	0.30	9342.83	952.38
5th Floor	912.83	3.00	2738.49	8832.38	0.30	9653.92	984.09
4th Floor	912.83	3.00	2738.49	8832.38	0.30	9653.92	984.09
3rd Floor	912.83	3.00	2738.49	8832.38	0.30	9653.92	984.09
Second floor	912.83	3.00	2738.49	9177.12	0.30	9998.67	1019.23
First floor	912.83	3.00	2738.49	9177.12	0.30	9998.67	1019.23
Ground floor			0.00	3808.61		3808.61	388.24
Under ground floor			0.00	721.22		721.22	73.52
Total mass							**12565.67**

Step 4: Determine Base shear, F_b

Step 4.1: Determine Base shear for building with C-25 concrete

S_d (T_1) = 0.654 m/s^2 m = 14,687.47 t λ = 1

F_b = 0.654 m/s^2*14,687.47 t*1 = **9,601.93 KN**

Step 4.2: Determine Base shear for building with C-40 concrete

S_d (T_1) = 0.654 m/s^2 m = 12565.67 t λ = 1

F_b = 0.654 m/s^2*12565.67 t*1 = **8,217.95 KN**

Step 5: Distribution of base shear, F_i

Step 5.1: Distribution of base shear for building with C-25 concrete

Table C.36 Distribution of base shear for G+12 building with C-25 concrete

Story	Z_i (m)	m (ton)	$Z_i.m_i$ (m.ton)	F_b (KN)	F_i (KN)
Roof	44.60	796.11	35506.48	9601.93	979.40
12th Floor	41.40	1038.60	42997.84	9601.93	1186.04
11th Floor	38.20	1038.60	39674.33	9601.93	1094.36
10th Floor	35.00	1072.08	37522.86	9601.93	1035.02
9th Floor	31.80	1072.08	34092.20	9601.93	940.39
8th Floor	28.60	1106.35	31641.65	9601.93	872.79
7th Floor	25.40	1106.35	28101.32	9601.93	775.14
6th Floor	22.20	1106.35	24561.00	9601.93	677.48
5th Floor	19.00	1138.94	21639.77	9601.93	596.90
4th Floor	15.80	1138.94	17995.17	9601.93	496.37
3rd Floor	12.60	1138.94	14350.58	9601.93	395.84

Story	Z_i (m)	m (ton)	$Z_i.m_i$ (m.ton)	F_b (KN)	F_i (KN)
Second floor	9.40	1197.14	11253.10	9601.93	310.40
First floor	6.20	1197.14	7422.25	9601.93	204.73
Ground floor	3.00	447.77	1343.32	9601.93	37.05
Total			348101.87		

<u>Step 5.2</u>: Distribution of base shear for building with C-40 concrete

Table C.37 Distribution of base shear for G+12 building with C-40 concrete

Story	Z_i (m)	m (ton)	$Z_i.m_i$ (m.ton)	F_b (KN)	F_i (KN)
Roof	44.60	631.56	28167.54	8217.95	664.98
12th Floor	41.40	893.35	36984.62	8217.95	873.13
11th Floor	38.20	893.35	34125.90	8217.95	805.64
10th Floor	35.00	918.89	32161.22	8217.95	759.26
9th Floor	31.80	918.89	29220.76	8217.95	689.84
8th Floor	28.60	952.38	27238.03	8217.95	643.03
7th Floor	25.40	952.38	24190.42	8217.95	571.08
6th Floor	22.20	952.38	21142.81	8217.95	499.14
5th Floor	19.00	984.09	18697.71	8217.95	441.41
4th Floor	15.80	984.09	15548.62	8217.95	367.07
3rd Floor	12.60	984.09	12399.54	8217.95	292.73
Second floor	9.40	1019.23	9580.78	8217.95	226.18
First floor	6.20	1019.23	6319.24	8217.95	149.18
Ground floor	3.00	388.24	1164.71	8217.95	27.50
Total			296941.91		

<u>Step 6</u>: Determine point of center of mass,(X_m, Y_m)

The same as the above value. (i.e the load apply at diaphragm center of mass)

C.3.2.2 EARTHQUAKE LOAD ANALYSIS USING RESPONSE SPECTRUM METHOD

Modal response spectrum type of analysis shall be applied to buildings which do not satisfy the conditions given in section 4.3.3.2.1 on ES EN 8:2015 for applying the lateral force method of analysis. The buildings satisfied nearly the conditions stated on section 4.3.3.2.1; the fundamental periods of vibration T_1 less than 2 second, the slenderness $\lambda = L_{max}/L_{min}$ of the building in plan is less than 4 and nearly meet the criteria for regularity in elevation given in section 4.2.3.3 on ES EN 8:2015. However, the buildings has little un-symmetry in terms of lateral stiffness and mass distribution with respect to two orthogonal axes. Moreover, the building is long in Y direction (39.5m long) and short in X direction (18m long) with curve around the front part. The building is symmetrical with respect to X axis but somewhat un-symmetric with respect to Y axis. Since the building is not symmetrical in plan with respect to two orthogonal axes and there is somewhat un-symmetry in mass distribution analyzing the building using modal response spectrum method in addition to lateral force method to have accurate sample structural design and to know accurately the effect of concrete grade enhancer admixture on structural design of high rise building.

Modal response spectrum analysis can be done using manually or structural analysis software such as ETABS. Since, this research includes structural analysis and design of three buildings, G+2, G+7 & G+12 each with floor area of 912 m^2, floor height of 3.2m, eight frames in Y direction and four frames in X direction, manual calculation to determine all parameters to know modal equivalent forces is too tedious and time taking.

Considering difficulty of manual calculations, ETABS 2013 is used for this research to determine equivalent modal forces using modal response spectrum analysis method.

Procedure for modal response spectrum analysis using ETABS 2013

Step 1: Define modal case;

Step 2: Define mass source for dead load and live load with self-weight multiply factor of 1 and 0.3 respectively;

Step 3: Define response function as per ES EN 8:2015;

Step 4: Define load case as response spectrum for EQ_X and EQ_Y;

Step 5: Define auto load type for EQ_X and EQ_Y as user coefficient.

C.4 MODELING AND ANALYSIS

C.4.1 MODELING

Modeling is the simulation and drafting of the actual 3D appearance of the building to analysis the structure for a given load. There are various type of finite element software like SAP2000, ETABS, SAFE12 to model and analysis structures. For this research all buildings are model and analyze using ETABS including reinforced concrete design to check the adequacy of the trial section before staring manual design of beam, column, slab and foundation.

C.4.1.1 MODELING OF G+2 BUILDING

Modeling and analysis procedure using ETABS 2013

Step 1: Select the unit (KN, M, C), set the number of grid lines (13 in X, 6 in Y), set the number of story (4 in Z) with base height of 1.5m and floor height of 3.2m, edit grid data and story height.

Step 2: **Define material**

The material is concrete, unit weight = 25KN/m^3, mass per unit volume = 2549.29 kg/m^3, elastic modules = 28.847595Gpa for C-25 concrete and 32.49Gpa for C-40 concrete, poison ratio is 0.2, thermal coefficient = 9.9x10^{-6}/^{0}c, compressive concrete strength, f_{ck} =20mpa for C-25 concrete and f_{ck} =32mpa for C-40 concrete and rebar with unit weight = 77KN/m^3, mass per unit volume = 7851.815 kg/m^3, elastic modules = 200Gpa, poison ratio is 0.3, thermal coefficient = 1.17x10^{-5}/^{0}c, tensile strength, f_{yk} =300mpa.

Step 3: **Define structural element section**

Step 3.1 Define structural element section for building with C-25 concrete

The trial frame sections are; CD30 for all floor columns, GB25X40 for grade beam, FB25x40 for first and second floor beams, LB25X40 for landing beams, RB25X30 for roof beams and S15 for floor and roof slabs.

Step 3.2 Define structural element section for building with C-40 concrete

The trial frame sections are; CD25 for all floor columns, GB20X35 for grade beam, FB20x35 for first and second floor beams, LB20X35 for landing beams, RB20X30 for roof beams and S15 for floor and roof slabs.

Step 4: **Define diaphragm**

Define diaphragm as GF, 1ST, 2ND, and RF for ground, first, second and roof diaphragms respectively.

Step 5: **Define load pattern**

Load pattern defined as DL, LL, EQ_X, and EQ_Y for dead, live, earthquake in X and earthquake in Y respectively.

Step 6: **Define load case**

Define load case as dead, live, EQ_X, and EQ_Y with linear static load case type.

Step 7: **Define load combination**

The load on the structure are dead load, live load, earth quake and wind load. In all combination either earth quake or wind load is selected based on their value since we assume that the probability of occurrence that two forces at the same time very rear. Here the maximum wind load and earth quake on story are;

- Maximum negative wind force = -0.98*43.5*3.2 = **-136.42 KN**
- Maximum positive wind force = 0.7*22*3 = **46.2 KN**
- Maximum earthquake load = **1276.25 KN**

Since the earth quake is much larger than wind force, earth quake is selected for load combination with live load and dead loads. Thus, the possible load combination are;

1. Comb1 = $1.35G_k+1.5Q_k$
2. Comb2 = 0.75comb1 + EQ_X
3. Comb3 = 0.75comb1 - EQ_X
4. Comb4 = 0.75comb1 + EQ_Y
5. Comb5 = 0.75comb1 - EQ_Y
6. Comb6 = Envelop
7. $G_k + Q_k$

<u>Step 8</u>: **Draw**

Draw beams, slabs and columns by create line and column tool. Click create column or line tool and select the appropriate section before draw. (Here, draw and assign of section the frame done simultaneously by gird method using draw tools.

<u>Step 9</u>: **Slab Meshing**

During analysis, ETABS automatically meshes (divides) shell objects that are assigned deck properties or slab properties with membrane behavior only. Meshing helps distribute loads realistically. The floor slabs are meshing with auto meshing option of coarse size 1.5x1.5m.

<u>Step 10</u>: **Assigning**

The load of walls, floor finish assign on slabs as area dead loads with area live load on all floor slabs. Moreover, diaphragm and support type are assigned.

<u>Step 11</u>: **Analyze** – Run the analysis

<u>Step 12</u>- Design – Here in these package (ETABS) design for different structure are possible like reinforced concrete using different code. For this research Euro code 2 2004 is used for comparison and cross-check the design result with the software result, since Euro code 2 result almost similar to our code ES EN;2015.

<u>Remark C.2</u>: All the design in this research is done manually, just design using ETABS is done only to compere the manual design result with the software result.

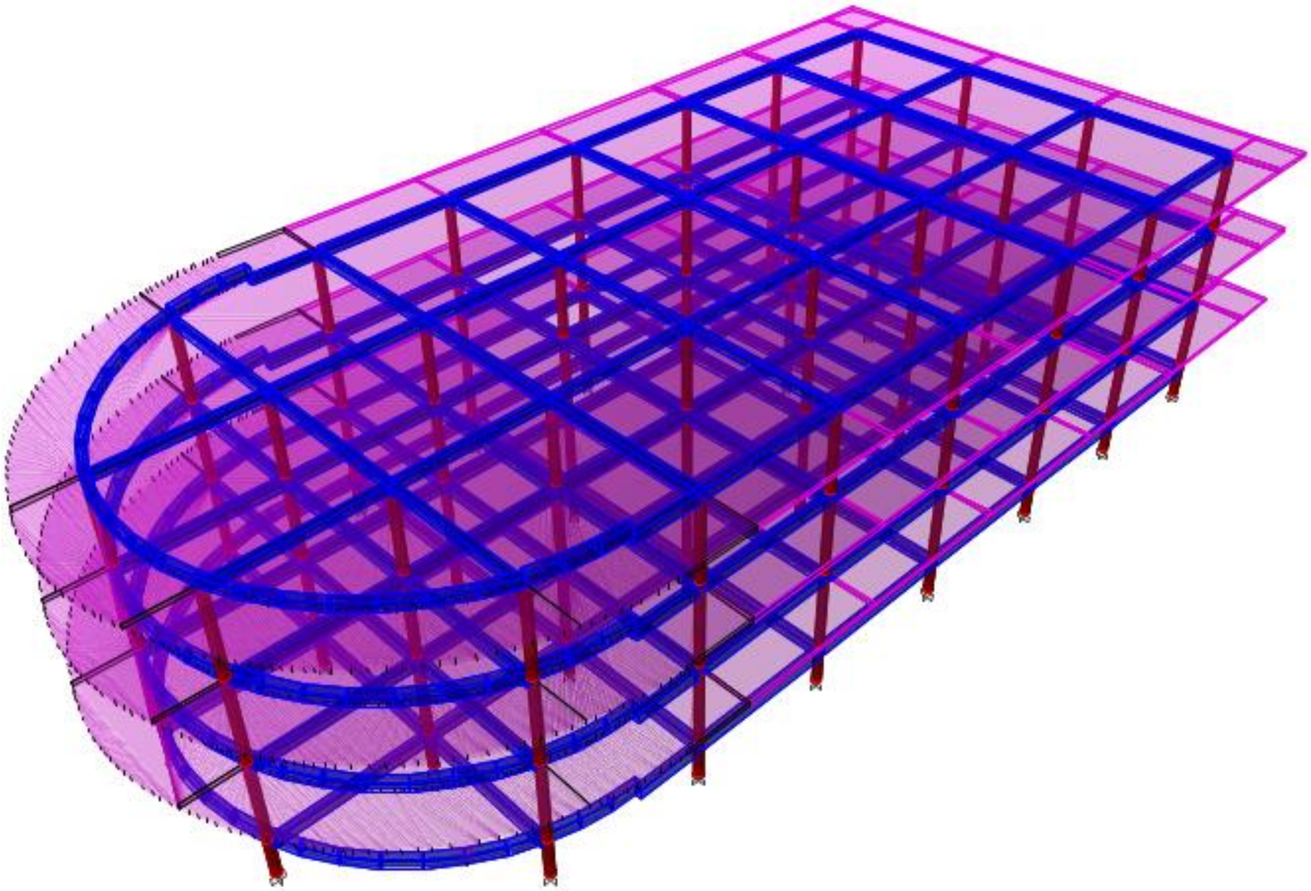


Figure C.17 3D modeling for G+2 building

Step 11: **Section revision and re-analysis** – Some of the sections assumed at beginning of modeling is not enough to resist the desire load; thus section revision and re-analysis is done for few frame sections.

C.4.1.2 MODELING OF G+7 BUILDING

Procedure of structural modeling for G+7 is similar to that of structural modeling procedures for G+2 building except some differences in steps discussed below.

Step 1: Set the number of story (9 in Z) with base height of 3m and floor height of 3.2m.

Step 3: **Define structural element section**

Step 3.1 Define structural element section for building with C-25 concrete

The trial frame sections are; CD60 for foundation, first and second floor columns, CD50 for 3rd-5th floor columns, CD40 for 6th-7th floor columns, GB30X45 for grade beam, FB30x45 for first and second floor beams, FB30x40 for 3rd-5th floor beams, FB25x40 for 6th-7th floor beams, LB25X40 for landing beams, RB25X30 for roof beams and S17 for floor and roof slabs.

<u>Step 3.2</u> Define structural element section for building with C-40 concrete

The trial frame sections are; CD50 for foundation, first and second floor columns, CD40 for 3^{rd}-5^{th} floor columns, CD30 for 6^{th}-7^{th} floor columns, GB30X40 for grade beam, FB30x40 for first and second floor beams, FB25x40 for 3^{rd}-5^{th} floor beams, FB25x35 for 6^{th}-7^{th} floor beams, LB25X35 for landing beams, RB20X30 for roof beams and S15 for floor and roof slabs.

<u>Step 4</u>: Define diaphragm

Define diaphragm as GF, 1ST, 2ND, 3RD, 4TH, 5TH, 6TH, 7TH and RF for ground, first, second, third, fourth fifth, sixth, seventh and roof diaphragms respectively.

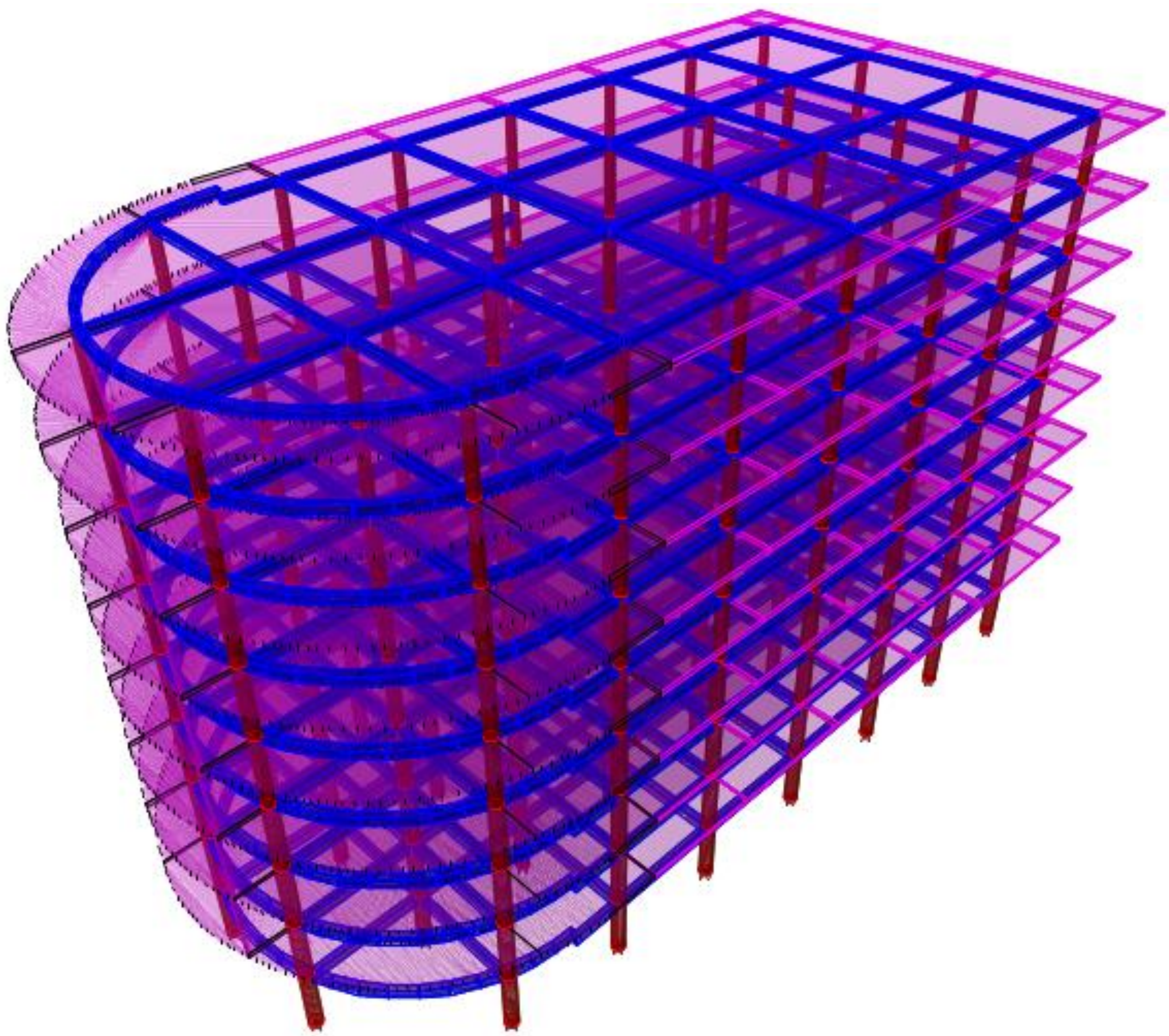


Figure C.18 3D modeling for G+7 building

C.4.1.3 MODELING OF G+12 BUILDING

Procedure of structural modeling for G+12 is similar to that of structural modeling procedures for G+2 building except some differences in steps discussed below.

Step 1: Set the number of story (14 in Z) with base height of 3m and floor height of 3.2m.

Step 3: **Define structural element section**

Step 3.1 Define structural element section for building with C-25 concrete

The trial frame sections are; CD80 for foundation, first and second floor columns, CD70 for 3rd-5th floor columns, CD60 for 6th-8th floor columns, CD50 for 9th-10th floor columns, CD40 for 10th-11th floor columns, GB35X55 for grade beam, FB35x55 for first and second floor beams, FB30x50 for 3rd-5th floor beams, FB30x45 for 6th-8th floor beams, FB30x40 for 9th-10th floor beams, FB25x40 for 11th-12th floor beams, LB25X40 for landing beams, RB25X35 for roof beams and S20 for floor and roof slabs.

Step 3.2 Define structural element section for building with C-40 concrete

The trial frame sections are; CD70 for foundation, first and second floor columns, CD60 for 3rd-5th floor columns, CD50 for 6th-8th floor columns, CD40 for 9th-10th floor columns, CD30 for 10th-11th floor columns, GB30X50 for grade beam, FB30x50 for first and second floor beams, FB30x45 for 3rd-5th floor beams, FB30x40 for 6th-8th floor beams, FB25x40 for 9th-10th floor beams, FB25x35 for 11th-12th floor beams, LB25X35 for landing beams, RB20X30 for roof beams and S15 for floor and roof slabs.

Step 4: **Define diaphragm**

Define diaphragm as GF, 1ST, 2ND, 3RD, 4TH, 5TH, 6TH, 7TH, 8TH, 9TH, 10TH, 11TH, 12TH and RF for ground, first, second, third, fourth, fifth, sixth, seventh, eighth, ninth, tenth, eleventh, twelfth and roof diaphragms respectively.

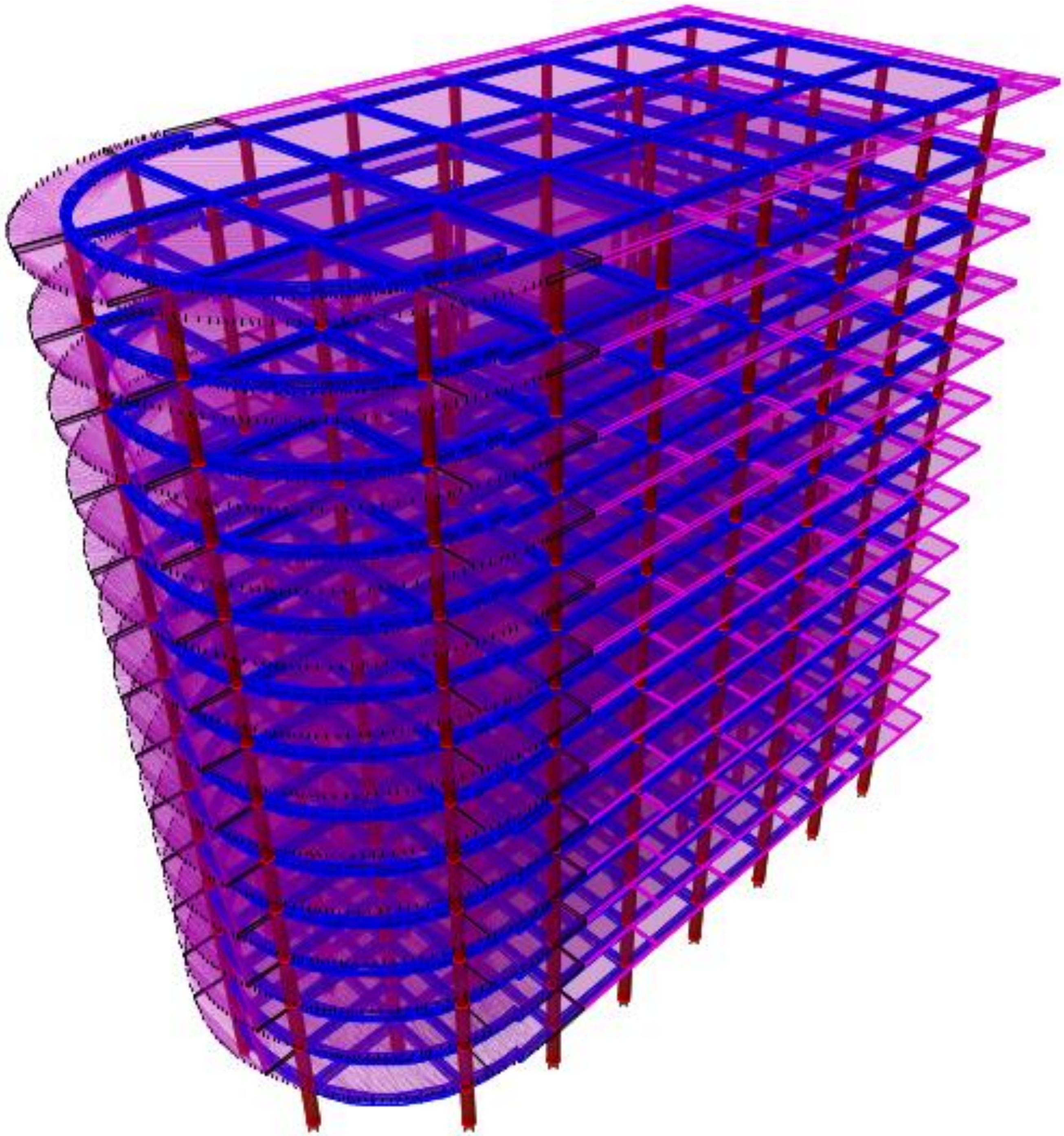


Figure C.19 3D modeling for G+12 building

C.5 SAMPLE STRUCTURAL DESIGN

C.5.1 SAMPLE STRUCTURAL DESIGN FOR C-25 CONCRETE

C.5.1.1 SAMPLE STRUCTURAL DESIGN FOR G+2 BUILDING WITH C-25 CONCRETE

C.5.1.1.1 SAMPLE SLAB DESIGN FOR G+2 BUILDING WITH C-25 CONCRETE

Slabs are horizontal members which used for functional occupancy for different activities in the building. Slabs can be constructed using solid concrete, hollow block concrete, composite of steel with concrete or using structural steel plates. Generally slabs broadly classified as solid, ribbed and flat slabs. The choice of different type of slabs depend on the functional requirement, strength, durability and cost. Ribbed slab is economical for buildings with light up to moderate loads and long spans such as aspartames buildings, hospitals and mixed used buildings. Whereas solid slab and flat slab is chosen when there is large loads and the building possible susceptible for moisture; such as residential building, large multipurpose buildings, hotels.

In these thesis all the floors are designed using solid slab. The analysis of solid slab can be done using various method such as Rankine-Grashoff's Approximate Method, strip method, coefficient method and the like. The Rankine-Grashoff's Approximate Method is suitable for analysis of two-way simply supported slab if corners are not held down (truly simply supported slab); whereas coefficient method is used only for rectangular two way edge supported slabs. But the strip method used for any type of slab such as rectangular slab with hole, circular slab and other advanced case like triangular slab.

Solid slab can be two way or one way based on the ratio of the larger span with shorter span length. In this research coefficient method is used for analysis of normal rectangular two way slabs.

Remark 5.2 The new code ES EN 2:2015 has no moment coefficient table for analysis and design of two way solid slab. Following that the old code EBCS 2, 1995 is used for sample slab design.

Analysis of Two-way Rectangular Slab using Coefficients method as per EBCS-2, 1995

EBCS-2, 1995 Code provide moment coefficient table for analysis of rectangular slab panels subjected to uniformly distributed load with provision for torsion at the corners depending on aspect ratios, l_y/l_x and support conditions of slab. Maximum moments for individual slab panels with edges either simply supported (discontinuous) or fully fixed (continuous) are given by;

$M_i = \alpha_i \cdot (gd + qd) \cdot l_x^2$ ………………………………………………......Equation A.1, EBCS 2, 1995

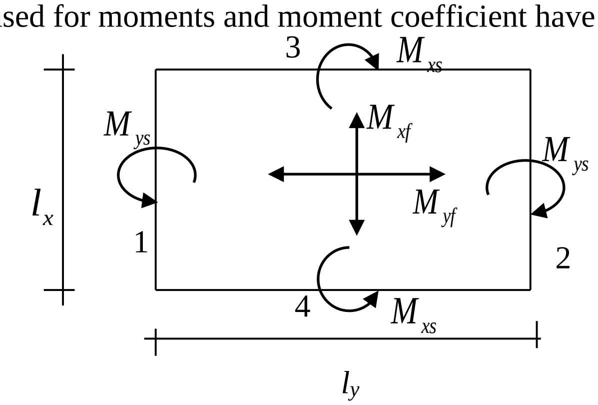
Where:

M_i is Design moment per unit width,

α_i is moment coefficient given by code based on ratio, l_y/l_x and support condition (EBCS 2, Table A-1),

l_x & l_y is the shorter and longer span length of slab panel respectively.

Subscripts used for moments and moment coefficient have the following meaning;



s - Support [-Negative moment]

f - Field or span [positive moment]

x - Direction of shorter span

y - Direction of longer span

Figure C.20 Slab Moment

The maximum support and span moments per unit width develop at particular critical points of slab panel of two-way system are given by the following equations;

$M_{xs} = \alpha_{xs}.P_d.l_x^2$ $\quad$ $M_{ys} = \alpha_{ys}.\ P_d.l_x^2$ $\quad$ $M_{xf} = \alpha_{xf}.\ P_d.l_x^2$ $\quad$ $M_{yf} = \alpha_{yf}.\ P_d.l_x^2$

The positive moment coefficients in EBCS 2, 1995 table A-1 may be derived from the following equations. The negative moment coefficients are taken as 4/3 times the positive moment coefficients for the same direction.

$$\alpha_{yf} = \frac{24 + 2n_d + 1.5\, n_d^2}{1000} \text{...Equation A.2, EBCS 2, 1995}$$

$$\alpha_{xf} = \frac{\beta}{(\sqrt{1 + r_4} + \sqrt{1 + r_3}} \text{ .... Equation A.3, EBCS 2, 1995}$$

$$\beta = \frac{2}{3}\left\{(1 - \frac{L_x}{L_y}\sqrt{2\alpha_{yf}}(\sqrt{r_1 + 1} + \sqrt{1 + r_2})\right\} \text{................................ Equation A.4, EBCS 2, 1995}$$

where; n_d is the number of discontinuous edges ($0 < n_d < 4$) r_1, r_2, r_3, r_4 are the ratios of negative moment capacity at edges 1 to 4, respectively, to the span moment capacity in the same direction and take values of 4/3 for continuous edges or zero for discontinuous edges.

Analysis and design procedure for two way rectangular slab

Step1: Determination of depth from deflection requirement (d)

$$d \geq (0.4 + 0.6\,\frac{f_{yk}}{400})\frac{L_e}{\beta_a} \text{ .... (Equation 5.3 on EBCS 2, 1995)}$$

Where:

f_{yk} is the characteristic strength of the reinforcement (mpa),

L_e is the effective span; and, for two-way slabs, the shorter span, β_a is the constant from table 5.1, on EBCS 2 based on support condition.

Step 2: Calculation of factored design load (P_d)

$g_k = W_P + W_S + W_{CS} + W_{ff} + W_{pw} + SDL$ $\quad P_d = 1.35g_k + 1.5q_k$ $\quad W = t.\gamma_m$

Where:

W_p is weight of plastering, W_s is weight of slab, W_{cs} is weight of cement screen,

W is material weight, γ_m is unit weight of material, t is thickness

W_{ff} is weight of floor finish, W_{pw} is weight of wall, and SDL is supper imposed dead load.

The unit weight of material is taken from table A.1 – A.11 and the live load is taken from table 6.2 on ES EN 1: 2015 for floors and table 6.10 for roof. The live load of functional rooms and unit weight of material used in this building summary in the table shown below.

Table C.38 Live loads

Room	Category	q_k (KN/m^2)
Toilet, Kitchen	A	1.5-2
Stair	A	2-4
Shop	D_1	4-5
Roof	H	0.4
Average for floor		3

Table C.39 Unit weight of materials

Material	γ (KN/m^3)
Reinforced concrete	25
Light Weigh Concrete	9-20
Porcelain	27
Waterproof membrane	16
Aluminum	27
Mortar	23

Step 3: Calculation of design moment (M_i)

Step 4: check the depth for maximum bending moment (d)

$$d_m > \sqrt{\frac{M}{0.8bfyd\rho\,(1-0.4\rho m)}} \qquad \rho = 0.75\rho bal \qquad \varepsilon yd = \frac{fyd}{E}$$

$$\rho_{bal} = \frac{0.8fcd}{fyd}\left(\frac{\varepsilon cu}{\varepsilon cu + \varepsilon yd}\right) \qquad m = \frac{fyd}{0.8fcd}$$

Step 5: Support moment adjustment - For support moments in which their differences exceed 20%, they must be adjusted by moment distribution.

Step 6: Filed moment adjustment – the span moment affected during support moment adjustment; thus we need to apply moment adjustment for field moments.

$\Delta M_{xf} = C_x\,\Delta M_{xs} + C_x\,\Delta M_{ys}$ $\quad \Delta M_{yf} = C_x\,\Delta M_{xs} + C_x\,\Delta M_{ys}$ $\quad \Delta M_{xf} = C_y\,\Delta M_{xs} + C_y\,\Delta M_{ys}$

$\Delta M_{yf} = C_y\ \Delta M_{xs} + C_y\ \Delta M_{ys}$ $\qquad M_{xf\ adj} = M_{xf} + \Delta M_{xf}$ $\qquad M_{yf\ adj} = M_{yf} + \Delta M_{yf}$

The coefficients C_x and C_y are taken from table A-2 on EBCS 2, 1995.

<u>Step 7</u>: Reinforcement calculation - There are three method to compute area of steel; formula method, general design chart method and table/K_d method. Among the three method we use the formula method, since it is easy for creating excel template.

$\rho_{\min} = \frac{0.5}{f_{yk}}$ ……………………………………………………………Equation 7.16 EBCS 2, 1995

$A_s = \rho bd$ $\qquad \rho = \frac{1}{2}(C_1 - \sqrt{{C_1}^2 - \frac{4M}{bd^2 C_2}})$ $\qquad C_1 = \frac{2.5}{m}$ $\qquad C_2 = 0.32m^2 f_{cd}$ $\qquad m = \frac{f_{yk}}{0.8 f_{cd}}$

<u>Remark C.3</u>- Moment adjustment is not applied, since its effect is not significant.

<u>Step 8</u>: Load transfer to the beam

According to EBCS-2, 1995, the design loads on supporting beam and the design shear-force of two-way slab subjected to a uniformly distributed load considering torsion at corners may be determined using the following equation.

$V_x = \beta_{vx}\ .(g_d + qd).\ l_x$ …………………………………………………Equation A.5, EBCS 2, 1995

$V_y = \beta_{vy}\ .(g_d + qd)\ .\ l_y$ …………………………………………………Equation A.6, EBCS 2, 1995

Where: β_{vx}, β_{vy} are shear-force coefficient taken from table A-3 on EBCS 2, 1995, V_i the design shear

The design load on supporting beam is distributed over a length of 0.75 times the span length of beam.

<u>Step 9</u>: Detailing – The slab detailing shown on appendix D

<u>Analysis and design of curved solid slabs</u>

The analysis of curved slabs can be done using advanced strip method, but these method are tedious and time taking. In this research design of curved slab is done by converting the curved panel to equivalent rectangular panel. Once the curved panel converted to equivalent rectangular panel, the slab analysis and design is the same as analysis and design of two way or one way solid slab.

Following the above procedures, the analysis and design of solid slab for typical floor slabs (1^{st} and 2^{nd} floors) is done using excel temple for both C-25 and C-40 concrete types.

Table C.40 Sample slab design for G+2 building using C-25 concrete

DESIGN OF TWO WAY SOLID SLAB BASED ON ES EN:2015

SAMPLE SLAB DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building

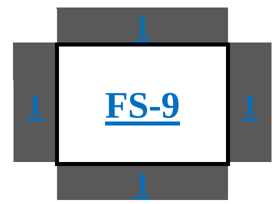
Description: Analysis & Design of 1st floor slab

Date: 7-May-18

Design by: Yohannes Sefiw

1. Material Constant

f_{cu} (mpa)	25	Design Strength (mpa)	
f_{yk} (mpa)	300	f_{cd}=	11.33
Cover [mm]	15	f_{yd}=	260.87



β_a for 2:1	β_a for 1:1	L_y/L_x	β_a
35.00	45.00	1.09	44.09

2. Depth Determination

Panel Name	FS-9		d_{eff} required [mm]	D required [mm]	D provided [mm]
Depth	L_x [m]	L_y [m]			
	5.50	6.00	106.03	130.00	150

3. Total Load calculation

Description	Thickness	Unit wt.	Load
Slab	0.15	25	3.75
Floor finish	0.02	27	0.54
Ceiling Plaster	0.02	23	0.46
Cement Screed	0.03	23	0.69
Partition Wall	0.10	14	0.80
Total Dead Load g_k (KN/m^2)			6.24
Live Load q_k (KN/m^2			3
Design load P_d (KN/m^2)			**12.92**

Partial safety factor	
γ_{DL}	1.35
γ_{LL}	1.50

wall Description	
Height (m)	3.05
Length (m)	5.50

4. Total Moment calculation

	ρ_1	ρ_2	ρ_3	ρ_4	n_d
ρ values	1.333	1.333	1.333	1.333	0.000
Moment Coefficient	a_{xs}	a_{ys}	a_{xf}	a_{yf}	β
	0.037	0.032	0.028	0.024	0.26
Moment (KN-m/m)	M_{xs}	M_{ys}	M_{xf}	M_{yf}	
	14.46	12.51	10.94	9.38	

5 Reinforcement Calculation

k-value	850	730	640	550
ρ	0.34	0.29	0.25	0.21
A_{min}[mm²]	218	218	218	218
As_{req} [mm²]	440	379	330	281
As_{prv} [mm²]	440	379	330	281
Ø (mm)	8	8	8	8
No of Bars/panel	56	43	41	33
S_{max} [mm]	300	300	300	300
S_{Cal}[mm]	110.00	130.00	150.00	170.00

Wall on beam TS

Wall Length	5.50 m
Beam Length	5.50 m
Thickness	0.004 m
Wall Height	2.85 m
γ(KN/m³)	27.00
G_k (KN/m)	0.31

S_{prv} [mm]	110.00	130.00	150.00	170.00

6 Total Un-factor Load transfer to beams

	Load Transfer on Beams			L_y/L_x = 1.09
Shear coeffcient	V_{bxc}	V_{bxd}	V_{byc}	V_{byd}
	0.361	0.000	0.330	0.000
Load on Beams	R_{cx}	R_{dx}	R_{cy}	R_{dy}
Total design load	18.33	N.A.	16.76	N.A.
Live Load	5.95	N.A.	5.45	N.A.
Dead Load	12.37	N.A.	11.32	N.A.

Note:- N.A.-Means Not Applicable

Input data 1 - Continuous

0 - Discontinuous

Wall on beam BS

Wall Length	5.50 m
Beam Length	5.50 m
Thickness	0.004 m
Wall Height	2.85 m
γ(KN/m³)	27.00
G_k (KN/m)	0.31

DL from wall on beam LS

Wall Length)	6.00 m
Beam Length	6.00 m
Thickness	0.10 m
Wall Height	2.85 m
γ(KN/m³)	14.00
G_k (KN/m)	3.99

Wall on beam RS

Wall Length	6.00 m
Beam Length	6.00 m
Thickness	0.10 m
Wall Height	2.85 m
γ(KN/m³)	14.00
G_k (KN/m)	3.99

C.5.1.1.2 SAMPLE STAIRCASE DESIGN FOR G+2 BUILDING WITH C-25 CONCRETE

Staircase is design as one way solid slab; the only difference in the case of staircase is the flight is inclined slab and analyze by project the inclined to horizontal. The analysis is the same as the analysis of one way slab; it is analyzed by taking the whole width of the stair and model as beam.

Analysis and design procedure for staircase

Step1: Determination of depth from deflection requirement

Step 2: Calculation of factored design load

Step 3: Calculation of design moment – the design moment is computed by taking one meter strip and analysis the slab as a beam using SAP2000.

Step 4: Check the depth for maximum bending moment – the depth required for maximum moment is 125.3mm, which is less than the provided staircase depth.

Step 5: Reinforcement calculation

Step 6: Load transfer to the beam – The load transfer to beam is the reaction for slab and taken from SAP2000.

Following the above procedures analysis and design of staircase has been done using excel template.

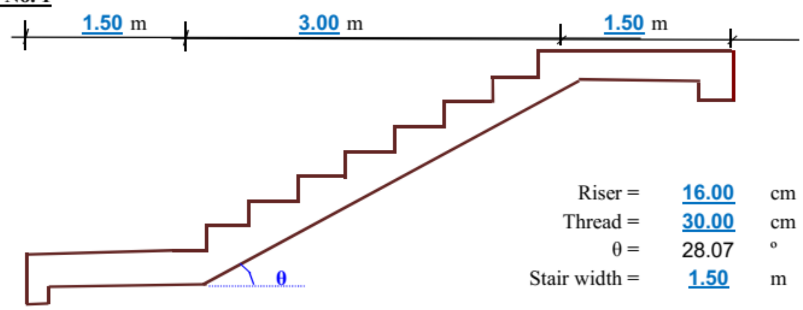
DESIGN OF STAIRCASE BASED ON ES EN:2015

SAMPLE STAIRCASE DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building **Date:** 10-May-18

Description: Analysis and Design of Staircase **Design by:** Yohannes Sefiw

1. Stair No. 1



Riser = 16.00 cm
Thread = 30.00 cm
θ = 28.07 °
Stair width = 1.50 m

2. Materials constant:

Concrete:	**C-** 25	f_{cu}= 20	f_{cd}= 11.33	Cover
Steel:	**S-** 300	f_{yk}= 300	f_{yd}= 260.87	15

3. DepthUsed:

$$d = \left(0.4 + 0.6\frac{f_{yk}}{400}\right)\frac{L_x}{\beta_a}$$

β_a = 28

Required d = 182.14 mm
Required D 204.1429
Provided D 250 mm
Provided d = **228.00** mm **OK!**

4. Loading:

I. Load on flight:

- Own wt. of slab (Waist) =	10.63	KN/m
- Due to steps per unit run =	3.00	KN/m
- 3cm cement screed =	0.69	KN/m
- 3cm Marble floor finish =	0.81	KN/m
On thread =	2.25	KN/m
On riser =	3.37	KN/m
- 1.5cm plastering =	0.59	KN/m
Total Dead Load on Stair	**19.83**	**KN/m**

- Live Load 3 KN/m^2

Live load per unit meter = **4.50** **KN/m**

Design Load = 1.35DL + 1.5LL

Pd= **33.52** **KN/m**

II. Load on Landing:

- Own wt. of slab =	9.38	KN/m
- 3cm cement screed =	1.04	KN/m
- 3cm terrazzo floor finish =	1.22	KN/m
- 1.5cm plastering =	0.52	KN/m
	12.14	**KN/m**

- Live load 3 KN/m^2

Live load per unit meter = **4.50** **KN/m**

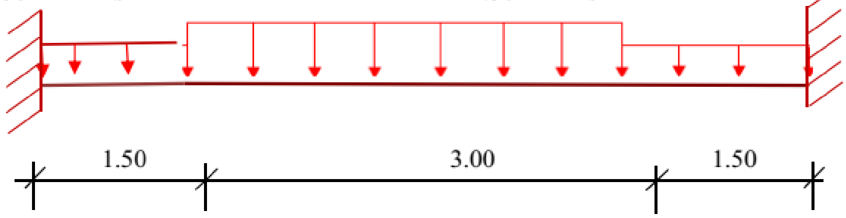
Design Load = 1.35DL + 1.5LL

P_d= **23.14** **KN/m**

5. Modeling

DL	12.14	KN/m	DL	19.83	KN/m	DL	12.14	KN/m
LL	4.50	KN/m	LL	4.50	KN/m	LL	4.50	KN/m

R1 84.99
DL 47.96
LL 13.50



R2 84.99
DL 47.96
LL 13.50

Design actions

Design Momen Negative = 90.83 KNm
Design Momen Posetive = 48.38 KNm
Design Shear = 84.99 KN

Load on Beam

	Length (m)	6.00
R1	DL (KN/m)	7.99
	LL (KN/m)	2.25
R2	DL (KN/m)	7.99
	LL (KN/m)	2.25

Check for Deflection

$$\Delta_{max} = \frac{wL^4}{384EI}$$

w = 20.49 KN/m
L = 6.00 m
E = 28.8 Gpa
I = 0.001953 m^4

Δ = 1.2 mm

- Final deflection shall not exceed the value:

$$\delta = \frac{L_e}{200} = 30.00 \text{ mm}$$ **OK!**

6. Check for Shear Capacity

$$V_c = 0.25 f_{ctd} k_1 k_2 b_w d$$

f_{ctd} = 1.03
K_1 = 1.08
K_2 = 1.37

$$\rho_{min} = \frac{0.5}{fyk}$$

ρ_{min} = 0.00167

Calculated Shear Capacity, V_c = 130.89 **OK!**

7. Reinforcement calculation

m = 28.77
C_1 = 0.09
C_2 = 3,002.3

-Main Reinforcement $A_s = \rho bd$ $\rho = \frac{1}{2}\left(C_1 - \left(\sqrt{C_1^2 - \frac{4M}{bd^2C_2}}\right)\right)$

Negative Reinforcement

Ø= 14 ρ = 0.00472
M = 90.83 KNm $A_{s,Prv}$ = 1614.87 mm^2

Spacing **Use Ø 14 C/C 140 mm**

Posetive Reinforcement

Ø= 10 ρ = 0.00245
M = 48.38 KNm $A_{s,Prv}$ = 836.98 mm^2

Spacing **Use Ø 10 C/C 140 mm**

-Secondary Reinforcement

Ø = 10 $A_{s,Prv}$ = 570.00 mm^2

Spacing **Use Ø 10 C/C 200 mm**

Figure C.21 Sample staircase design for G+2 building using C-25 concrete

C.5.1.1.3 SAMPLE BEAM DESIGN FOR G+2 BUILDING WITH C-25 CONCRETE

Beam is design for bending moment, shear force and torsional force. In this research the magnitude of torsion is small for almost for all beams. Following that, for this research sample beam design is done for bending moment and pure shear.

Procedure for flexure design

Step 1: Determine design strength, f_{cd}, f_{yd}

Step 2: Determine depth for deflection, d – according to EBCS 2, 1995 equation 5.3 the minimum depth for deflection is given by;

$d \geq (0.4 + 0.6\frac{f_{yk}}{400})\frac{L_e}{\beta_a}$ ……………………………………………Equation 5.3 EBCS 2, 1995

Step 3: Determine effective depth

Step 4: Check ductility/check depth for bending moment

$d \geq \sqrt{\frac{M}{0.8.b.f_{yd}.\rho.(1-0.4\rho_m)}}$ $\rho = 0.75\rho_{bal}$ $\varepsilon_{yd} = f_{yd} / E$

$m = fyd/(0.8fcd)$ $\rho_{bal} = 0.8fcd/fyd(\varepsilon cu/(\varepsilon cu + \varepsilon yd)$

Step 5: Reinforcement calculation, A_S

- Steel ratio,

  $\rho_{min} = 0.6/f_{yk}$ ……………………………………………………Equation 7.2, EBCS 2, 1995
- Minimum Reinforcement area, $A_{smin} = \rho_{min}bd$
- Calculated area of reinforcement $As = \rho bd$
- Maximum area of reinforcement – according to EBCS 2, 1995 section 7.2.1.1 the maximum steel ratio for either tensile or compressive reinforcement is 0.04. Thus the maximum area of reinforcement is; $As_{max} = 0.04bd$.

Step 6: Detailing – detailing for longitudinal reinforcement is done on appendix D.

Procedure for pure shear design

Step 1: Determine design strength, f_{cd}, f_{yd} , f_{ctd}

Step 2: Determine shear resistance, V_{RD}, V_c

- Diagonal compression resistance,

  $V_{RD} = 0.25f_{cd}bd > V_{sd}$………………………………..…….Equation 4.28, EBCS 2: 1995
- Concrete shear resistance,

  $V_c = 0.25f_{ctd}k_1k_2bd$………………...........………………Equation 4.29, EBCS 2: 1995

  $K_1 = 1+50\rho \leq 2$ $\rho = As/(bd)$ $K_2 = 1.6 - d \geq 1$

Step 3: Reinforcement calculation

- Calculated stirrup spacing - $S_{cal} = A_v f_{yd} d/V_s$ $A_v = 2a_s$ $V_s = V_{sd} - V_c$
- Minimum reinforcement –

  $\rho_{min} = 0.4/f_{yk}$ ……………………………………...……Equation 7.13, EBCS 2: 1995
- Maximum spacing is the minimum of the following values

  $S_{max} = 0.5d < 300mm$ for $2/3V_{RD} > V_{sd}$……………………Equation 7.14, EBCS 2: 1995

  $S_{max} = 0.3d < 200mm$ for $2/3V_{RD} < V_{sd}$ ……..........................Equation 7.15, EBCS 2, 1995

Step 4: Detailing: Sample structural detailing for beam given on appendix B.

Following the above procedures sample beam design is computed using excel template.

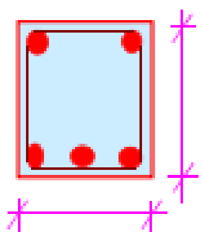
DESIGN OF BEAM BASED ON ES EN:2015

SAMPLE BEAM DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building Date: 10-May-18

Description: Analysis and Design of Floor Beam Design by: Yohannes Sefiw

1. First floor beam (on axis B span 4-3)



Depth	0.40	m
Width	0.25	m
$Ø_m$	0.024	m
Cover	0.025	m

2. Effective depth calculation

$d_{eff} = D - Cover - Ø_m/2 - Ø_s$

$d_{eff} =$ 0.355 m

3. Depth for defflection

$L_{e\,(m)} =$ 6.00

$\beta_a =$ 28.00

$$d \geq \left(0.4 + \frac{f_{yk}}{400}\right)\frac{L_e}{\beta_a}$$

d (m) = 0.246 OK!

4. Design bending moment and shear force

Design Negative Moment Mu = 119.24 kN-m

Design Positive Moment Mu = 56.18 kN-m

Design Shear Force, Vsd = 96.90 KN

5. Material constant

Concrete Grade C- 25

$f_{ck} =$ 20,000 kpa

$f_{ctk} =$ 1,547 kpa

$\gamma c =$ 1.5

$f_{cd} =$ 11,333 kpa

$f_{ctd} =$ 1,032 kpa

$E_{cm} =$ 28,848 kpa

$f_{ck} = 0.8 f_{cu}$

$f_{ctk} = 0.21 f_{ck}^{2/3}$

$f_{cd} = 0.85 f_{ck}/\gamma_c$

$f_{ctd} = f_{ctk}/\gamma_c$

$E_{cm} = 9.5(f_{ck}+8)^{1/3}$

$f_{yd} = f_{yk}/\gamma_s$

$\rho_{min} = \frac{0.6}{f_k}$

Steel Grade S- 300

fyk = 300,000.0 kpa

$\gamma s =$ 1.15

fyd = 260869.57 kpa

Es = 200000.00 kpa

$\rho_{min} = 0.002$

$\rho_{max} = 0.04$

6. Design for flexure

$$\rho_{req} = \frac{1}{m}\left[1-\sqrt{1-\frac{2m_u}{f_{cd}bd^2}}\right] \qquad m = \frac{f_{yd}}{f_{cd}} \qquad \mu = \frac{M_u}{f_{cd}bd^2}$$

$\rho = Max(\rho_{req}, \rho_{min})$

$As = \rho bd$

Negative Reinforcement			Positive Reinforcement		
m =	23.02		m =	23.02	
μ =	0.330		μ =	0.156	
Check Ducklity -	OK!		Check Ducklity -	OK!	
Beam Type -	Double Reinforced!		Beam Type -	Single Reinforced!	
ρ_{req} =	0.0181		ρ_{req} =	0.0074	
As_1 =	0.00162	m^2	As_1 =	0.00066	m^2
As_2 =	0.00015	m^2	As_2 =	0.00000	m^2
$Ø_m$ =	20		$Ø_m$ =	16	
n_1 =	5.15		n_1 =	3.28	
n_2 =	0.46		n_2 =	0.00	
Use	6 Ø 20		Use	4 Ø 16	
As_{prvd} =	0.00188		As_{prvd} =	0.0008	
Capacity =	132.88	KN-m	Capacity =	67.13	
Reserve =	10.26%		Reserve =	16.31%	

7. Design for Shear

$V_{Rd} = 0.25\ fcd\ b_w\ d > V_{sd}$ V_{Rd} = 202.30 KN   Check Shear Resistance - **OK!**

$V_c = 0.25\ f_{ctd}\ k_1 k_2 b_w d$ V_s = 38.08 KN

$K1 = 1+50\rho < 2$ k_1 = 2.056

$k_2 = 1.6 - d > 1$ k_2 = 1.243

$\rho = As/bd$

V_c = 58.82 KN

$S_{max} = 0.5d < 300mm$ for $2/3V_{RD} > V_{sd}$

$S_{max} = 0.3d < 200mm$ for $2/3V_{RD} < V_{sd}$

$S_{prv} = Min(S_{cal}, S_{max})$

Shear Reinforcement

$$s = \frac{A_v d f_{yd}}{V_s} \qquad V_s = V_{sd} - V_c$$

A_v = 0.00010 S_{max} = 178.5 mm

$Ø_s$ = 8 S_{cal} = 245.9 mm

S_{prv} = 170 mm

Use Ø 8 C/C 170 mm

Figure C.22 Sample beam design for G+2 building with C-25

C.5.1.1.4 SAMPLE COLUMN DESIGN FOR G+2 BUILDING WITH C-25 CONCRETE

Column is primarily design to resist axial force; it may be uniaxial or bi-axial depending on the moment act on the column. In 3D frame system almost all columns are bi-axial column. In this research all buildings have 30 columns or foundations at the base and each of them may have different axial force. But design for each of them based on their axial force value is not practical in construction and it is tedious in design. Thus, column grouping based on their axial force diagram is necessary within a certain axial force interval; base on the base axial force value the columns grouped as follow shown in the table below.

Table C.41 Column grouping for G+2 building with C-25 concrete

Axis	P (KN)	Interval	Group	Axis	P (KN)	Interval	Group
A-2	1254.64	1201-1600	C-1	E-2	1294.14	1201-1600	C-1
A-3	1249.02	1201-1600	C-1	E-3	1417.88	1201-1600	C-1
B-1	1229.8	1201-1600	C-1	E-4	1214.77	1201-1600	C-1
B-2	1213.98	1201-1600	C-1	F-1	1237.12	1201-1600	C-1
B-3	1237.85	1201-1600	C-1	F-2	1474.04	1201-1600	C-1
B-4	1219.24	1201-1600	C-1	F-3	1363.87	1201-1600	C-1
C-1	1089.65	801-1200	C-2	F-4	1131.52	801-1200	C-2
C-2	1273.79	1201-1600	C-1	G-1	1094.14	801-1200	C-2
C-3	1236.37	1201-1600	C-1	G-2	1396.75	1201-1600	C-1
C-4	1050.7	801-1200	C-2	G-3	1376	1201-1600	C-1
D-1	1125.22	801-1200	C-2	G-4	1062.3	801-1200	C-2
D-2	1178.55	801-1200	C-2	H-1	919.42	801-1200	C-2
D-3	1327.39	1201-1600	C-1	H-2	1148.53	801-1200	C-2
D-4	1135.84	801-1200	C-2	H-3	1136.89	801-1200	C-2
E-1	1228.76	1201-1600	C-1	H-4	909.27	801-1200	C-2

As clearly shown on table 5-41, the column grouped in to two groups based on their base axial force; C-1 for axial force ranges between 1201 to 1600 KN and C-2 for axial force ranges between 801 to 1200 KN. In the interval the maximum axial force is taken for foundation design as shown in the table below;

Table C.42 Maximum axial force in each column group for G+2 with C-25 concrete

Interval	P_{max} (KN)	Location of P_{max}	Group	No Member
0-400	-	-	C-4	-
401-800	-	-	C-3	-
801-1200	1178.55	Axis D-2	C-2	12
1201-1600	1474.04	Axis F-2	C-1	18

Column have two type of reinforcement, the main vertical bars and the horizontal tie bars. The vertical main bars are designed based for bi-axial bending and the vertical bar designed for shear. The shear force value in most columns is small and the maximum spacing is mostly provided for column main bar confinement.

Design procedure for column design

Step 1: Determine design strength, f_{cd}, f_{yd}, f_{ctd};

Step 2: Determine ratio, d'/h for circular columns to choose column chart;

d' = cover $+\phi_m/2 + \phi_s$

Step 3: Determine frame mode (sway or non-sway) – According to EBCS 2 the frame is non sway if;

$\frac{N6}{HL} \leq 0.1$……………………………………………………………Equation 4.3 EBCS2, 1995

Where: N and H are the vertical and horizontal reactions at the bottom of the story respectively;

σ is the horizontal displacement at the top of the story relative to the bottom story

L is story height.

Step 4: Determine effective length, L_e – According to EBCS 2 the ratio of effective length to length for non-sway, sway and conservatively respectively as given below.

$\frac{L_e}{L} = \frac{\alpha_m+0.4}{\alpha_m+0.8} \geq 0.7$ For non-sway……………………………………Equation 4.8 EBCS2, 1995

$\frac{L_e}{L} = \sqrt{1+0.8\alpha_m} \geq 1.1$ For sway………………………………….. Equation 4.9 EBCS2, 1995

$\frac{L_e}{L} = \sqrt{\frac{7.5+4(\alpha_1+\alpha_2)+1.6\alpha_1\alpha_2}{7.5+\alpha_1+\alpha_2}} \geq 1.15$ For conservatively……………..Equation 4.10 EBCS2, 1995

$\alpha_m = \frac{\alpha_1+\alpha_2}{2}$ $\alpha = \frac{\sum EI_{Col}/L_{Col}}{\sum E\beta I_b/L_b}$

β = 1 for opposite end elastically or rigidly restrained, β = 1 for opposite end free to rotate and β = 0 for cantilever beam.

Step 5: Determine slenderness ratio

Calculated slenderness ratio – $\lambda_{Cal} = \frac{L_e}{i}$ $i = \sqrt{\frac{I}{A}}$

Limiting slenderness ratio – According to EBCS 2, 1995 the slenderness ration is not exceed 140

And second order moment is no consider for the following case;

1. Sway frame, $\lambda \leq 25$ or $\lambda \leq \frac{15}{\sqrt{U_d}}$

$U_d = N_{sd}/f_{cd}A_c$……………..……..Equation 4.6, EBCS 2, 1995

2. Non-sway frame,

$\lambda \leq 50 - 25\frac{M_1}{M_2}$……...……………..……….…..Equation 4.7, EBCS 2, 1995

Where

M_1 and M_2 are first order moments at the ends, M_2 being always positive and greater in magnitude than M_1 and M_1 being positive if member is bent in single curvature and negative if bent in double curvature.

Step 6: Design eccentricity, e_{tot} – according to EBCS 2 section 4.4.10.2 equation 4.14 the total design column eccentricity is given by;

$e_{tot} = e_e + e_a + e_e$ ………………………………………….… Equation 4.14, EBCS 2, 1995

$0.6e_{02} + 0.4e_{01}$ or $e_e = 0.4e_{02}$………………………..………………. Equation 4.16, EBCS 2, 1995

Where: e_{01} and e_{02} are the first-order eccentricities at the ends, e_{02} being positive and greater in magnitude than e_{01}.

$$e_a = \frac{L_e}{300} \geq 20mm$$

$e_2 = \frac{K_1 L_e^2}{10}(\frac{1}{\gamma})$………………………………………………………… Equation 4.18, EBCS 2, 1995

$\frac{1}{\gamma} = k_2(\frac{5}{d})10^{-3}$ …………………………..……. ……………………Equation 4.19, EBCS 2, 1995

$K_1 = l/20 - 0.75$ for $15 \leq \lambda \leq 35$ $K_1 = 1.0$ for $\lambda > 35$ $K_2 = M_{sd}/M_b$

For different eccentricities at the ends, the critical end section shall be checked for first-order moments;

$e_{tot} = e_{02} + e_a$ ……………………………………………………..……. Equation 4.17, EBCS 2, 1995

Step 7: Reinforcement calculation

1. Main/longitudinal reinforcement

According to section 7.2.4.2 EBCS 2, 1995 the area of longitudinal reinforcement shall not be less than 0.008Ac nor more than 0.08Ac. The minimum number of longitudinal reinforcing bars shall be 6 for bars in a circular arrangement.

Minimum reinforcement, $As_{min} = 0.008A_c$ Maximum reinforcement, $As_{max} = 0.08A_c$

Calculated reinforcement, $As = \text{Ш} f_{cd}A_c/f_{yd}$ Where: Ш is read from column chart based on μ and v values. $\mu = M_{sd}/f_{cd}A_c h$ $M_{sd} = N_{sd}e_{tot}$ $v = N_{sd}/f_{cd}A_c$

2. Stirrups/ lateral reinforcement

According to section 7.2.4.3 EBCS 2, 1995 the diameter of ties or spirals shall not be less than 6 mm or one quarter of the diameter of the longitudinal bars. The center to center spacing of lateral reinforcement shall not exceed;

- 12 times the minimum diameter of longitudinal bars
- least dimension of column or 300mm

Calculated stirrup spacing - $S_{cal} = A_v f_{yd} d/V_s$ $A_v = 2a_s$ $V_s = V_{sd} - V_c$

Maximum spacing- S_{max} – the maximum spacing for stirrup along longitudinal direction is given by;

$$S_{max} = Min(12\phi_m, b_{min}, 300mm)$$

Following the above procedures, sample structural design for column is done using excel template.

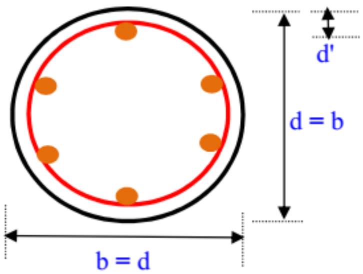
DESIGN OF CIRCULAR COLUMN BASED ON ES EN:2015

SAMPLE COLUMN DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

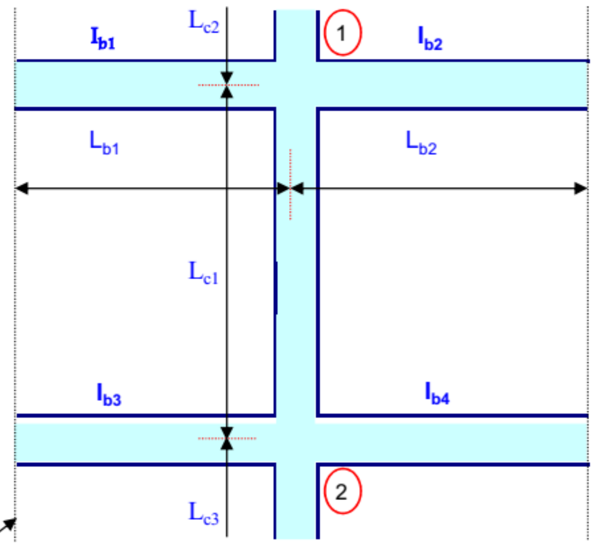
Building Type: Mixed Use Building **Date:** 23-May-18

Description: Design of Column for G+2 Building (C-25) **Design by:** Yohannes Sefiw

1. C-2 (Ground floor Column) Combo-3



column cross-section



Center line of near by column

Column elevation

2. Material constant

Concrete - Grade C- 25 Steel - Grade S- 300

f_{ck}	20000	kpa	$f_{ck} = 0.8 f_{cu}$	F_{yk}	300000	kpa
f_{ctk}	1547.2932	kpa	$f_{ctk} = 0.21 f_{ck}^{2/3}$	γs	1.15	
γc	1.5			F_{yd}	260,870	kpa
f_{cd}	11333.333	kpa	$f_{cd} = 0.85 f_{ck}/\gamma_c$	E_s	200,000	kpa
f_{ctd}	1031.5288	kpa	$f_{ctd} = f_{ctk}/\gamma_c$	$A_{s\,(min)}$	0.0008	m^2
E_{cm}	28847.595	kpa	$E_{cm} = 9.5(f_{ck}+8)^{1/3}$	$A_{s\,(max)}$	0.007693	m^2

3. Analysis Result:

Axial (kN)	Mom. x-x	Mom y-y
904.65	-60.54	-11.58
849.26	127.33	16.08

4. Structure Classification:

Second-order global elastic analysis was done. Therefore both sway and non-sway are taken care of.

5. Dimensions in x-x direction:

Item	Depth	Width
B_1 =	0.40	0.25
B_2 =	0.40	0.25
B_3 =	0.40	0.25
B_4 =	0.40	0.25
C_1 =	0.35	0.35
C_2 =	0.35	0.35
C_3 =	0.35	0.35

6. Dimensions in y-y direction:

Item	Depth	Width
B_1 =	0.40	0.25
B_2 =	0.40	0.25
B_3 =	0.40	0.25
B_4 =	0.40	0.25
C_1 =	0.35	0.35
C_2 =	0.35	0.35
C_3 =	0.35	0.35

L_{b1} =	5.50		L_{b1} =	6.00
L_{b2} =	6.00		L_{b2} =	6.00
L_{c1} =	3.20		L_{c1} =	3.20
L_{c2} =	3.20		L_{c2} =	3.20
L_{c3} =	1.50		L_{c3} =	1.50

7. Limits of Slenderness:

$$\lambda \le 50 - 25\left(\frac{M_1}{M_2}\right)$$

$\frac{M_1}{M_2}$ = -0.48 $\qquad$ $\frac{M_1}{M_2}$ = -0.72

$\lambda \le$ 61.89 $\qquad$ $\lambda \le$ 68.00

But, the slenderness ratio is:

$$\lambda = \frac{L_e}{i} \qquad i = \text{Radius of gyration} = \sqrt{\frac{I_g}{A_g}}$$

A_g = 0.096 m^2

I_g = 0.00074 m^4

i = 0.088

L_e = Effective buckling length

8. Effective Buckling Length:

$$L_e = \frac{\alpha_m + 0.4}{\alpha_m + 0.8} L \ge 0.7L \qquad \alpha_1 = \frac{I_{c1}/L_{c1} + I_{c2}/L_{c2}}{I_{b1}/L_{b1} + I_{b2}/L_{b2}}$$

$$\alpha_m = \frac{\alpha_1 + \alpha_2}{2} \qquad \alpha_2 = \frac{I_{c1}/L_{c1} + I_{c3}/L_{c3}}{I_{b3}/L_{b3} + I_{b4}/L_{b4}}$$

About x-x direction.				About y-y direction.			
I_{c1} =	0.00074	I_{c1} =	0.00074	I_{c1} =	0.00074	I_{c1} =	0.00074
I_{c2} =	0.00074	I_{c3} =	0.00074	I_{c2} =	0.00074	I_{c3} =	0.00074
I_{b1} =	0.00133	I_{b3} =	0.00133	I_{b1} =	0.00133	I_{b3} =	0.00133
I_{b2} =	0.00133	I_{b4} =	0.00133	I_{b2} =	0.00133	I_{b4} =	0.00133
α_1 =	**0.990**	α_2 =	**1.552**	α_1 =	**1.035**	α_2 =	**1.622**
	α_m =	**1.271**			α_m =	**1.329**	

- the effective buckling length:

L_e = **2.582** $\qquad$ L_e = **2.599**

- Slenderness ratio:

λ = **29.508** **Not Slender** **Ignore Secondary Effects** $\qquad$ λ = **29.699** **Not Slender** **Ignore Secondary Effect**

9. Design Actions:

Calculate Eccentricities in the x-x Direction

$$\text{Total} = e_{tot} = e_e + e_a + e_2$$

$$e_e = \max \text{ of } \begin{cases} 0.6e_{02} + 0.4e_{01} \\ 0.4e_{02} \end{cases}$$

e_{01} = -0.0669

e_{02} = 0.1499

e_e = 0.0632 m

Calculate Eccentricities in the y-y Direction

$$\text{Total} = e_{tot} = e_e + e_a + e_2$$

$$e_e = \max \text{ of } \begin{cases} 0.6e_{02} + 0.4e_{01} \\ 0.4e_{02} \end{cases}$$

e_{01} = -0.0128

e_{02} = 0.0189

e_e = 0.0076

$e_a = \frac{L_e}{300} \geq 200mm$ $e_a = \frac{L_e}{300} \geq 200mm$

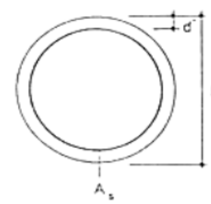
$e_a =$	0.02	m	$e_a =$	0.02	m
$e_2 =$	0.00	m	$e_2 =$	0.00	m
$e_{tot} =$	0.0832	m	$e_{tot} =$	0.0276	m
$N_{sd} =$	904.65	kN			
$M_{sd\ x\text{-}x} =$	75.26	kN-m	$M_{sd\ y\text{-}y} =$	24.94	kN-m

10. Reinforcement Calculation:

10.1 Axial Reinforcement

d'/h = 0.1 $e_{yd} = 0.002$ Use - **Uiaxial Chart No. 12**

$$\upsilon_{sd} = \frac{N_{sd}}{f_{cd} A_c} \qquad \mu_{sd,x-x} = \frac{M_{sd,x-x}}{f_{cd} A_c h} \qquad \mu_{sd,y-y} = \frac{M_{sd,y-y}}{f_{cd} A_c b}$$



$v_{sd} =$ 0.830 $\mu_{sd,x\text{-}x} =$ 0.197 $\mu_{sd,y\text{-}y} =$ 0.065

$\mu_{sd} =$ 0.197 $\mu_{sd} = \text{Max}(\mu_{sd,x\text{-}x}, \mu_{sd,y\text{-}y})$

$\acute{\omega} =$ 0.63

$$A_{s,tot} = \frac{\omega A_c f_{cd}}{f_{yd}}$$

$A_{s,\ min} < A_{s,\ prv} < A_{s,\ max}$

$A_{s,\ prv} = \text{Max}(A_{s,\ min}, A_{s,\ tot})$

$A_{s,\ tot} =$ **0.002632** m^2 $A_{s,\ prv} =$ **0.00263** m^2

$Ø_m =$ 20

No Bars= 8.38

Use 9 Ø 20

10.2 Check bar Congestion per layer

$$n_{max} = \frac{\Pi(D - 2C - 2Øs)}{Øm + S}$$

Cover, C (mm) = 25.00

Max Aggregate Size, S (mm) = 2.00

Max No Bars, n_{max} = 40

Status - **Ok! No bar congestion**

10.3 Shear Reinforcement

$V_{Rd} = 0.25 f_{cd} bd > V_{sd}$ $V_c = 0.25 f_{ctd} K_1 K_2 bd$ $K_1 = 1+50\rho < 2$ $k_2 = 1.6 - d > 1$

$\rho = As/bd$ $S_{cal} = A_v f_{yd} d/V_s$ $V_s = V_{sd} - V_c$ $A_v = 2a_s$

$S_{max} = \min[12Ø_m, b, 300mm]$

V_{RD} (KN)	Status	V_{sdx} (KN)	V_{sdy} (KN)
347.08	Ok!	134.96	7.24
K_1	K_2	V_c (KN)	
2.00	1.25	78.98	
Φ (mm)	S_{max} (mm)	S_{cal} (mm)	S_{prv} (mm)
10	240	256	240

Use Ø 10 C/C 240 mm

Figure C.23 Sample column design for G+2 building C-25 concrete

C.5.1.1.5 SAMPLE FOUNDATION DESIGN FOR G+2 BUILDING WITH C-25 CONCRETE

The lowest artificially built part of a structure which transmits the load of the structure to the ground is called foundation. The foundation of a structure is always constructed below ground level so as to increase the lateral stability of the structure. It includes the portion of the structure below ground level and other artificial arrangements in the form of concrete block, grillage, raft, piles etc. at its base so as to provide a firm and level surface for transmitting the load of the structure on a large area of the soil lying underneath.

Foundation has various type and their applicability of its type depend on various factors like soil condition, structure load, importance of the building, property boundary and other factors.

Foundation is selected after soil investigation; the choice of different type of foundation is depend on type of load and soil condition. In addition to this the property boundary condition also affect the choice foundation type. Considering Semera has ground type C (deep deposits of dense or medium-dense sand, gravel or stiff clay with thickness from several tens to many hundreds of meters.) with low to moderate structural load, isolated foundation is selected for sample foundation design. According to table 6.3 on EBCS 7, 1995, the allowable soil bearing capacity for dense sandy soil is 420 Kpa.

Foundation design include determine the economical section of footings, depth, width, length and reinforcement. The area of the pad depends the load of the structure and the soil bearing capacity. And the thickness is decided based on the section wide beam and punching shear. According to EBCS 7, 1995 equation 6.1 the ultimate design load, V_d should less than the design bearing capacity of the foundation, R_d.

<u>Procedure for isolated foundation design</u>

<u>Step 1</u>: **Bearing capacity**- The allowable bearing capacity of soil is determined from table 6.3 on EBCS 7, 1995;

<u>Step 2</u>: **Proportioning**- Area of foundation for ultimate bearing capacity, σ_{ult} and design load, P with factor of safety, F_s is given by;

$A = F_sP/\sigma_{ult} = P/\sigma_{all}$ for square footing, $A = B^2 = P/\sigma_{all}$, Thus, $B = \sqrt{P/\sigma all}$

<u>Step 3</u>: **Contact pressure** – the maximum and minimum contact pressure is computed as shown below and the section is safe against contact pressure if; $\sigma_{max} < \sigma_{ult}$

$\sigma_{max} = \frac{p}{A}\left(1 + 6\frac{e_x}{B} + 6\frac{e_y}{B}\right) \leq \sigma_{ult}$ $e_x = \frac{M_x}{p}$ $e_y = \frac{M_y}{p}$

$\sigma_{min} = \frac{p}{A}\left(1 - 6\frac{e_x}{B} - 6\frac{e_y}{B}\right)$ $\sigma_{ult} = F_s.\ \sigma_{all}$ $F_s = 2$

<u>Step 4</u>: **Thickness** – the depth of foundation is decided based on the punching and wide beam shear.

<u>Step 4.1</u>: **Thickness for punching**

The Punching shear resistance according to EBCS-2 equation 4.47 is given by;

$V_{Rd1} = 0.25f_{ctd}.K1.K2.U.d$, $K_1 = 1+50\rho$ $K_2 = 1.6-d$

$U = \Pi.h = \Pi\ (1.5d+D+1.5d) = \Pi\ (3d+D)$ for circular column, $\rho_{min} = 0.5/f_{yk}$

The critical section for punching is 1.5d from the face of the column

Developed shear, $V_1 = \sigma A$, $\sigma = \frac{\sigma 1+\sigma 2}{2}$ Where σ_1 and σ_2 are contact pressure at critical section

$$\sigma_1 = \sigma_{min} + \frac{(\frac{B-3d-D}{2})(\sigma_{max}-\sigma_{min})}{B} \qquad \sigma_2 = \sigma_{min} + \frac{(\frac{B+3d+D}{2})(\sigma_{max}-\sigma_{min})}{B} \qquad A = \frac{\Pi}{4}(3d+D)^2$$

Net developed shear, $V_{d1} = P - V_1$

The thickness is sufficient for punching shear if $V_{Rd1} > V_{d1}$

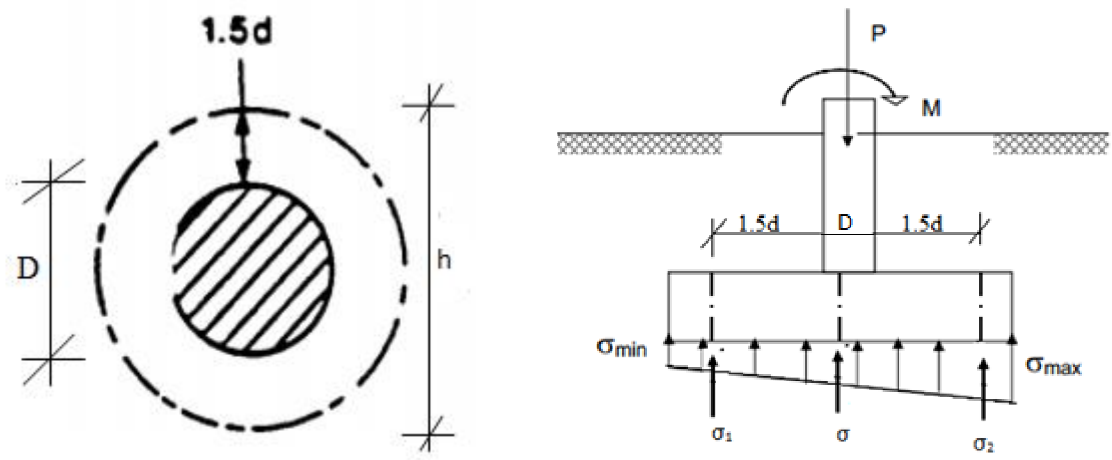


Figure C.24 Critical section for punching

4.2 Thickness for wide beam shear

The wide shear beam is developed at d distance from the face of the column

The wide beam shear resistance, $V_{Rd2} = 0.25f_{ctd}k_1k_2bd$

Developed wide beam shear, $V_{d2} = \sigma_1 A$, $\sigma_1 = \frac{\sigma+\sigma max}{2}$ Where σ is contact pressure at critical section

$$A = B\,\frac{B-D-2d}{2} \qquad \sigma = \sigma_{min} + \frac{(\frac{B+2d+D}{2})(\sigma_{max}-\sigma_{min})}{B}$$

The thickness is sufficient for wide beam shear if $V_{Rd2} > V_{d2}$

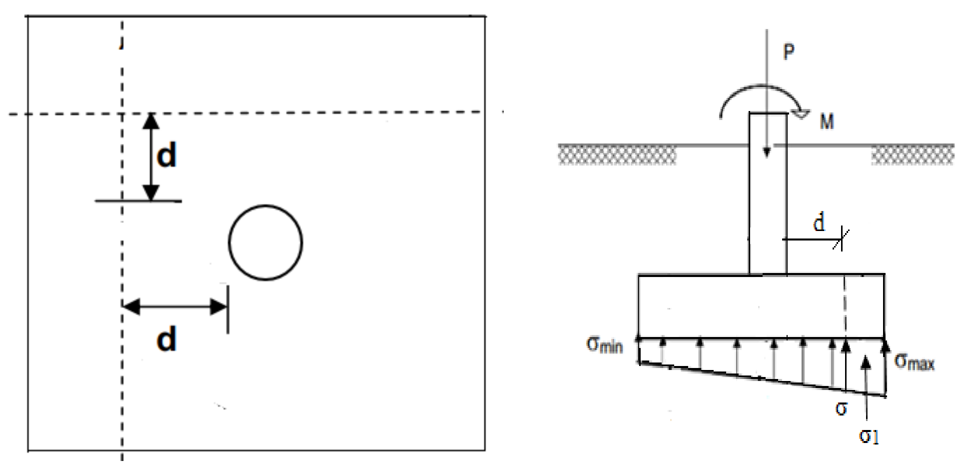


Figure C.25 Critical section for wide beam shear

Step 5: **Bending moment** – the moment is developed at the face of the column and computed by,

$M_{sd} = \sum \sigma.A.X = V_1X_1 + V_2X_2$ Where X is moment lever arm

$V_1 = \sigma_1 l$ $\quad V_2 = \sigma_2 l$ $\quad l = \frac{1}{2}(B-D)$ $\quad X_2 = \frac{1}{2} l$ $\quad X_1 = \frac{2}{3} l$

$\sigma = \sigma_{min} + \frac{(\frac{B+D}{2})(\sigma_{max}-\sigma_{min})}{B}$ $\quad \sigma_1 = \frac{\sigma_{max}-\sigma}{2}$ $\quad \sigma_2 = \sigma$

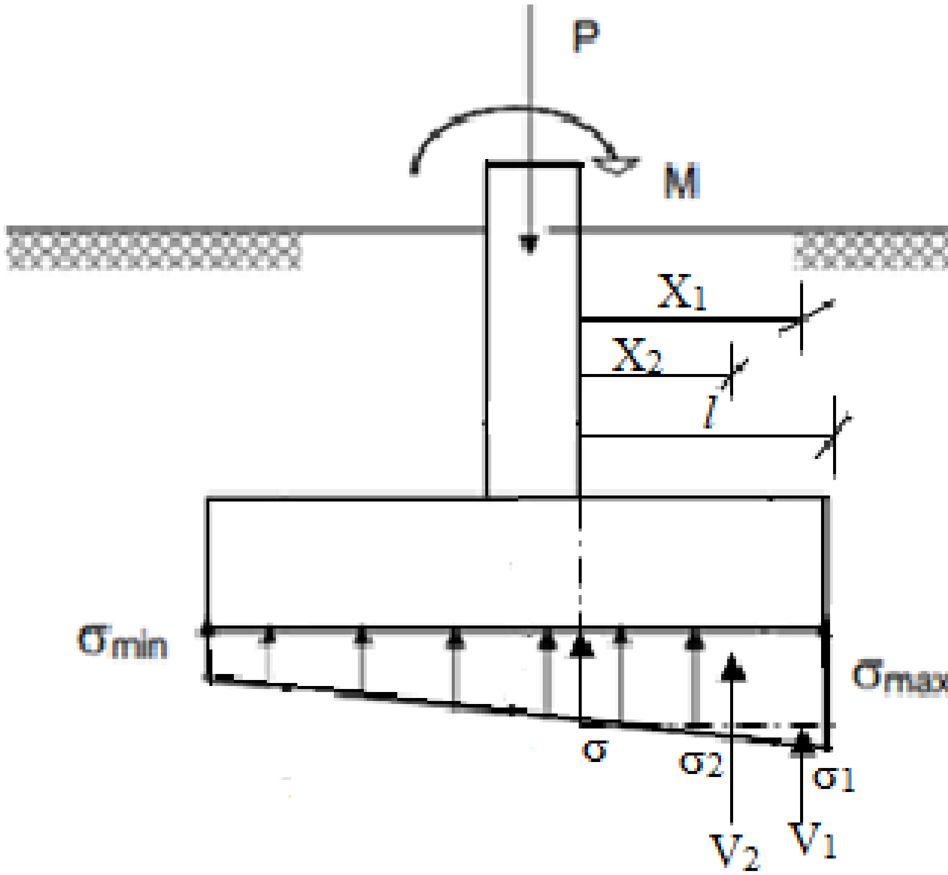


Figure C.26 Critical section for bending moment

<u>Step 6</u>: **Concrete moment capacity** – the concrete moment capacity is given by; $M = 0.32 f_{cd} bd^2$

<u>Step 7</u>: **Reinforcement calculation –** the area of reinforcement is given by;

The area of reinforcement, $A_s = \rho bd$ $\quad \rho = \frac{fcd}{fyd}\left[1 - \sqrt{1 - \frac{2Msd}{fcdbd2}}\right] \geq \rho_{min}$

Spacing, $S = \frac{bas}{As}$

<u>Step 8</u>: **Development length**, l_d – the length of bar for anchorage and bondage is given by;

$l_d = \frac{\phi fyd}{4fbd}$ $\quad f_{bd} = f_{ctd}$ $\quad l = \frac{B-D}{2}$ - Cover

Bend the bars upward with a minimum length of 10cm if the available length is less than the developed length.

<u>Step 9</u>: **Detailing** – The detailing for sample foundation is given on appendix D.

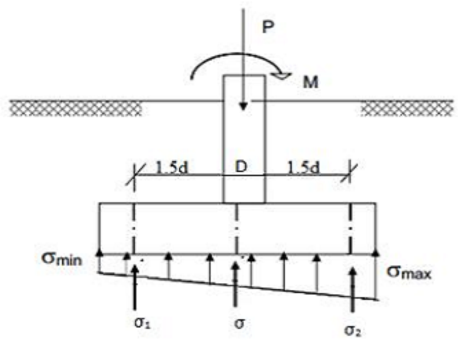
DESIGN OF SQUARE ISOLATED FOUNDATION BASED ON ES EN:2015

SAMPLE FOUNDATION DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building Date: 24-May-18

Description: Design of Square Isolated Foundation for G+2 Building (C-25) Design by: Yohannes Sefiw

1. Foundation 1 (F-1)



2. Material Constant

Concrete Grade C- 25

f_{ck} = 20,000.000000 kpa

f_{ctk} = 1,547.293229 kpa

γc = 1.50

f_{cd} = 11,333.333333 kpa

f_{ctd} = 1,031.528820 kpa

E_{cm} = 28,847.595233 kpa

Steel Grade S- 300

f_{yk} = 300,000.0000 Kpa

γs = 1.15

f_{yd} = 260,869.5652 Kpa

E_s = 200,000.0000 Kpa

Cover, C (mm) = 50

3. Soil Property

Ground Type - Dense sand

Facter of Safety, Fs = 2.00

$\sigma_{ult} = F_s.\ \sigma_{al}$ Allowble soil bearing capacity, σ_{all} = 420 Kpa

Ultimate Soil bearing capacity, σ_{ult} = **840** kpa

4. Proportioning

$A = B^2 = P/\sigma_{all,}$ $B = \sqrt{P/\sigma all}$ Axial force, P (KN) = 1474.05 Foundation Width, B (m) = **1.87**

Provided Foundation Width, B (m) = **1.90**

5. Contact pressure

$\sigma_{max} = \frac{P}{A}\left(1 + 6\frac{e_x}{B} + 6\frac{e_y}{B}\right) \leq \sigma_{ult}$ $\sigma_{min} = \frac{P}{A}\left(1 - 6\frac{e_x}{B} - 6\frac{e_y}{B}\right)$ $e_x = \frac{M_x}{P}$ $e_y = \frac{M_y}{P}$

M_x (KNm) = 221.94 e_x (m) = 0.1506 σ_{max} (Kpa) = 770.07 Area, A(m^2) = 3.61

M_y (KNm) = 191.60 e_y (m) = 0.1300 σ_{min} (Kpa) = 46.57 **Status -** **Ok! Area is adequate**

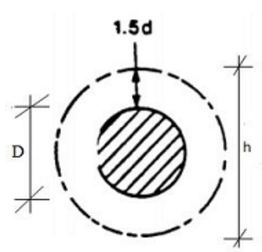
6. Foundation Thickness

Thickness, d (m) = **0.55** Column Diameter, D (m) = 0.40

6.1 Check trial foundation thickness for punching shear

The punching shear resistance, $V_{Rd1} = 0.25 f_{ctd}.K1.K2.U.d,$ $K_1 = 1+50\rho \leq 2$ $K_2 = 1.6 - d \geq 1$

$U = \Pi.h = \Pi\ (1.5d+D+1.5d) = \Pi\ (3d+D)$ For circular column Developed shear, $V_1 = \sigma A$, $\sigma = \frac{\sigma 1 + \sigma 2}{2}$



$\sigma_1 = \sigma_{min} + \frac{\left(\frac{B-3d-D}{2}\right)(\sigma_{max}-\sigma_{min})}{B}$ $\sigma_2 = \sigma_{min} + \frac{\left(\frac{B+3d+D}{2}\right)(\sigma_{max}-\sigma_{min})}{B}$

Net developed shear, $V_{d1} = P - V_1$ $\rho_{min} = 0.5/f_{yk}$ $A = \frac{\Pi}{4}(3d+D)^2$

The thickness is sufficient for punching shear if $V_{Rd1} > V_{d1}$ A (m^2) = 3.299

ρ_{min} = 0.0017 K_2 = 1.05 V_{Rd1} (KN) = **1039.06** V_{d1} (KN) = **127.00**

U (m) = 6.44 K_1 = 1.08 V_1 (KN) = 1347.05

σ_1 (Kpa) = 18.02 σ_2 (Kpa) = 798.633 σ (Kpa) = 408.324

Status - **Ok! Thickness is adequate for punching shear**

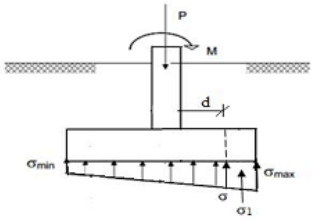
6.2 Check trial foundation thickness for wide beam shear

The wide beam shear resistance, $V_{Rd2} = 0.25f_{ctd}k_1k_2bd$

The thickness is sufficient for wide beam shear if $V_{Rd2} > V_{d2}$

Developed wide beam shear, $V_{d2} = \sigma_1 A$, $\sigma_1 = \frac{\sigma + \sigma max}{2}$

$A = B\,\frac{B-D-2d}{2}$ $\quad \sigma = \sigma_{min} + \frac{(\frac{B+2d+D}{2})(\sigma_{max}-\sigma_{min})}{B}$



V_{Rd2} (KN) = **306.54**

V_{d2} (KN) = **278.16**

σ (Kpa) = 693.916 $\quad \sigma_1$ (Kpa) = 731.995 $\quad$ A (m^2) = 0.38

Status - Ok! Thickness is adequate for wide beam shear

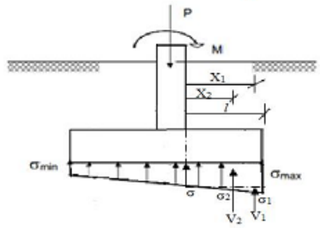
6.3. Check trial foundation thickness for bending moment

Developed moment, $M_{sd} = \sum \sigma.A.x = V_1X_1 + V_2X_2$ $\quad V_1 = \sigma_1 l \quad V_2 = \sigma_2 l$

$l = \frac{1}{2}(B - D) \quad X_2 = \frac{1}{2}l \quad X_1 = \frac{2}{3}l$ $\quad \sigma = \sigma_{min} + \frac{(\frac{B+D}{2})(\sigma_{max}-\sigma_{min})}{B}$

The concrete moment capacity, $M = 0.32f_{cd}bd^2$ $\quad \sigma_1 = \frac{\sigma_{max} - \sigma}{2}$

l = 0.75 $\quad X_2$ = 0.375 $\quad X_1$ = 0.500 $\quad \sigma_2 = \sigma$



σ (Kpa) = 484.48 $\quad \sigma_1$ (Kpa) = 142.796 $\quad \sigma_2$ (Kpa) = 484.482

V_1 (KN/m) = 107.1 $\quad V_2$ (KN/m) = 363.361 $\quad M_{sd}$ (KN-m/m) = **189.809**

M (KN-m/m) = **1097.07**

Status - Ok! The thickness is adequate for bending moment

7. Reinforcement Calculation

$A_s = \rho bd \quad \rho = \frac{fcd}{fyd}\left[1 - \sqrt{1 - \frac{2Msd}{fcdbd2}}\right] \rho_{min}$ $\quad$ Spacing, $S = \frac{bas}{As}$

ρ = 0.0025 $\quad A_s$ (mm^2) = **1361.7** $\quad$ **Ø = 16** $\quad$ S (mm) = **147.579**

Use Ø 16 C/C 140 mm

8. Development length

$l_d = \frac{\phi fyd}{4fbd}$ $\quad f_{bd} = f_{ctd}$ $\quad l_d$ (mm) = **1011.6** $\quad l = \frac{B-D}{2}$ - Cover $\quad l_{d,\,avl}$ (mm) = **700**

Status - Bend the bars upward with a minimum length of 100mm!

Figure C.27 Sample foundation design for G+2 building with C-25 concrete

C.5.1.2 SAMPLE STRUCTURAL DESIGN FOR G+7 BUILDING WITH C-25 CONCRETE

C.5.1.2.1 SAMPLE SLAB DESIGN FOR G+7 BUILDING WITH C-25 CONCRETE

Following similar procedure as sample design of slab for G+2 building, sample slab design for G+7 building is done as shown below.

Table C.43 Sample slab design for G+7 building using C-25 concrete

DESIGN OF TWO WAY SOLID SLAB BASED ON ES EN:2015

SAMPLE SLAB DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building $\quad$ **Date:** 13-May-18

Description: Analysis & Design of 2nd floor slab $\quad$ **Design by:** Yohannes Sefiw

1 Material Constant

Concrete Grade (f_{cu})	25	Design Material Strength (mpa)	
R.Steel Grade (f_{yk})	300	f_{cd}	11.33
Cover [mm]	15	f_{yd}	260.87

β_a for 2:1	β_a for 1:1	L_y/L_x	β_a
35.00	45.00	1.00	45.00

2 Depth Determination

Panel Name	FS-11		d_{eff} required [mm]	D required [mm]	D provided [mm]
Depth	L_x [m]	L_y [m]			
	6.00	6.00	113.33	140.00	170

3 Total Load calculation

Description	Thickness t	Unit weight	Load
Slab	0.17	25	4.25
Floor finish	0.02	27	0.54
Ceiling Plaster	0.02	23	0.46
Cement Screed	0.03	23	0.69
Partition Wall	0.004	27	0.16
		Total Dead Load gk (KN/m^2)	6.10
		Live Load qk (KN/m^2	3
		Design load P_d (KN/m^2)	12.74

Partial safety factor	
γ_{DL}	1.35
γ_{LL}	1.50

Wall Description	
Height (m)	2.10
Length (m)	17.65

4 Total Moment calculation

ρ values	ρ_1	ρ_2	ρ_3	ρ_4	n_d
	1.333	1.333	1.333	1.333	0.000
Moment Coefficent	α_{xs}	α_{ys}	α_{xs}	α_{ys}	β
	0.032	0.032	0.024	0.024	0.22
Moment (KN-m/m)	M_{xs}	M_{ys}	M_{xf}	M_{yf}	
	14.68	14.68	11.01	11.01	

5 Reinforcement Calculation

k-value	650	650	490	490
ρ	0.25	0.25	0.19	0.19
$A_{min}[mm^2]$	252	252	252	252
As_{req} $[mm^2]$	384	384	286	286
As_{prv} $[mm^2]$	384	384	286	286
Ø (mm)	8	8	8	8
No of Bars/panel	47	47	36	36
S_{max} [mm]	340	340	340	340
S_{Cal}[mm]	130.00	130.00	170.00	170.00
S_{prv} [mm]	130.00	130.00	170.00	170.00

Wall on beam TS

Length of wall (m)	6.00
Length of beam (m)	6.00
Wall Thickness (m)	0.20
Hieght of wall (m)	2.85
$\gamma(KN/m^3)$	14.00
Gk (KN/m)	7.98

6 Total Un-factor Load transfer to beams

	Load Transfer on Beams			L_y/L_x = 1.00
Shear coeffcient	V_{bxc}	V_{bxd}	V_{byc}	V_{byd}
	0.333	0.000	0.330	0.000
Load on Beams	R_{cx}	R_{dx}	R_{cy}	R_{dy}
Total design load	18.19	N.A.	18.03	N.A.
Live Load	5.99	N.A.	5.94	N.A.
Dead Load	12.20	N.A.	12.09	N.A.

Wall on beam BS

Length of wall (m)	6.00
Length of beam (m)	6.00
Wall Thickness (m)	0.20
Hieght of wall (m)	2.85
$\gamma(KN/m^3)$	14.00
Gk (KN/m)	7.98

Note:- N.A.-Means Not Applicable   1 -Continuous

input data   0 -Discontinous

Wall on beam LS

Length of wall (m)	6.00
Length of beam (m)	6.00
Wall Thickness (m)	0.20
Hieght of wall (m)	2.85
$\gamma(KN/m^3)$	14.00
Gk (KN/m)	7.98

Wall on beam RS

Length of wall (m)	6.00
Length of beam (m)	6.00
Wall Thickness (m)	0.20
Hieght of wall (m)	2.85
$\gamma(KN/m^3)$	14.00
Gk (KN/m)	7.98

C.5.1.2.2 SAMPLE STAIRCASE DESIGN FOR G+7 BUILDING WITH C-25 CONCRETE

The design value of staircase for G+7 building is the same as design value of staircase for G+2 building because of the architectural plan, staircase layout, height of riser, width of tread, staircase loading and other necessary parameters are the same with G+2 building.

C.5.1.2.3 SAMPLE BEAM DESIGN FOR G+7 BUILDING WITH C-25 CONCRETE

Following similar procedure as sample beam design of for G+2 building, sample beam design for G+7 building is done as shown below.

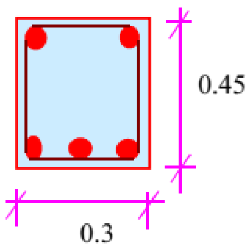
DESIGN OF BEAM BASED ON ES EN:2015

SAMPLE BEAM DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building — Date: 14-May-18

Description: Design of Beam for G+7 building with C-25 concrete — Design by: Yohannes Sefiw

1. Second floor beam (on axis D span 3-2)



Depth	0.45	m
Width	0.30	m
$\O_m$	0.024	m
Cover	0.025	m

2. Effective depth calculation

$d_{eff} = D - Cover - \O_m/2 - \O_s$

$d_{eff} = 0.405$ m

3. Depth for defflection

$L_{e\,(m)} = 6.00$

$\beta_a = 28.00$

$$d \geq (0.4 + \frac{f_{yk}}{400})\frac{L_e}{\beta_a}$$

d (m) = 0.246 **OK!**

4. Design bending moment and shear force

Design Negative Moment Mu = 167.68 kN-m

Design Positive Moment Mu = 68.15 kN-m

Design Shear Force, Vsd = 127.32 KN

5. Material constant

Concrete Grade C- 25

$f_{ck} =$ 20,000 kpa

$f_{ctk} =$ 1,547 kpa

$\gamma c =$ 1.5

$f_{cd} =$ 11,333 kpa

$f_{ctd} =$ 1,032 kpa

$E_{cm} =$ 28,848 kpa

$f_{ck} = 0.8 f_{cu}$

$f_{ctk} = 0.21 f_{ck}^{2/3}$

$f_{cd} = 0.85 f_{ck}/\gamma_c$

$f_{ctd} = f_{ctk}/\gamma_c$

$E_{cm} = 9.5(f_{ck}+8)^{1/3}$

$f_{yd} = f_{yk}/\gamma_s$

$\rho_{min} = \frac{0.6}{f_k}$

Steel Grade S- 300

fyk = 300,000.0 kpa

$\gamma s =$ 1.15

fyd = 260869.57 kpa

Es = 200000.00 kpa

$\rho_{min} = 0.002$

$\rho_{max} = 0.04$

6. Design for flexure

$$\rho_{req} = \frac{1}{m}\left[1 - \sqrt{1 - \frac{2m_u}{f_{cd}bd^2}}\right] \qquad m = \frac{f_{yd}}{f_{cd}} \qquad \mu = \frac{M_u}{f_{cd}bd^2}$$

$\rho = Max(\rho_{req}, \rho_{min})$

$As = \rho bd$

Negative Reinforcement

$m =$ 23.02

$\mu =$ 0.301

Check Ducklity - **OK!**

Beam Type - **Single Reinforced!**

$\rho_{req} = 0.0160$

Positive Reinforcement

$m =$ 23.02

$\mu =$ 0.122

Check Ducklity - **OK!**

Beam Type - **Single Reinforced!**

$\rho_{req} = 0.0057$

$As_1 = 0.00195\ m^2$ $As_1 = 0.00069\ m^2$

$As_2 = 0.00000\ m^2$ $As_2 = 0.00000\ m^2$

$Ø_m =$ **24** $Ø_m =$ **16**

$n_1 = 4.30$ $n_1 = 3.43$

$n_2 = 0.00$ $n_2 = 0.00$

Use **5 Ø 24** **Use** **4 Ø 16**

$As_{prvd} = 0.00226$ $As_{prvd} = 0.0008$

Capacity = 187.78 KN-m Capacity = 78.50

Reserve = 10.70% Reserve = 13.18%

7. Design for Shear

$V_{Rd} = 0.25\ fcd\ b_w\ d > V_{sd}$ $V_{Rd} = 286.88$ KN Check Shear Resistance - **OK!**

$V_c = 0.25\ f_{ctd}\ k_1 k_2 b_w d$ $V_s = 55.02$ KN

$K1 = 1+50\rho < 2$ $k_1 = 1.931$

Shear Reinforcement

$k_2 = 1.6 - d > 1$ $k_2 = 1.195$

$s = \dfrac{A_v d f_{yd}}{V_s}$ $V_s = V_{sd} - V_c$

$\rho = As/bd$ $A_v = 0.00010$ $S_{max} = 202.5$ mm

$V_c = 72.30$ KN $Ø_s =$ **8** $S_{cal} = 193$ mm

$S_{max} = 0.5d < 300mm$ for $2/3V_{RD} > V_{sd}$ $S_{prv} = 190$ mm

$S_{max} = 0.3d < 200mm$ for $2/3V_{RD} < V_{sd}$ **Use** **Ø 8 C/C 190 mm**

$S_{prv} = Min\ (S_{cal}, S_{max})$

Figure C.28 Sample beam design for G+7 building with C-25

C.5.1.2.4 SAMPLE COLUMN DESIGN FOR G+7 BUILDING WITH C-25 CONCRETE

Following similar procedure as sample column design of G+2 building, sample column design for G+7 building is done as shown below.

Table C.44 Column grouping for G+7 building with C-25 concrete

Axis	P (KN)	Interval	Group	Axis	P (KN)	Interval	Group
A-2	3970.64	3601-4000	C-3	E-2	4274.4	4001-4400	C-2
A-3	4005.07	4001-4400	C-2	E-3	4627.1	4401-4800	C-1
B-1	3879.49	3601-4000	C-3	E-4	3900.77	3601-4000	C-3
B-2	4058.53	4001-4400	C-2	F-1	3956.11	3601-4000	C-3
B-3	4058.53	4001-4400	C-2	F-2	4274.4	4001-4400	C-2
B-4	3910.58	3601-4000	C-3	F-3	4274.4	4001-4400	C-2
C-1	3652.53	3601-4000	C-3	F-4	3900.17	3601-4000	C-3
C-2	4186.41	4001-4400	C-2	G-1	3581.48	3201-3600	C-4
C-3	4096.55	4001-4400	C-2	G-2	4571.48	4401-4800	C-1
C-4	3559.53	3201-3600	C-4	G-3	4530.68	4401-4800	C-1
D-1	3674.29	3601-4000	C-3	G-4	3502.1	3201-3600	C-4
D-2	3926.29	3601-4000	C-3	H-1	3032.91	2800-3200	C-5
D-3	4356.94	4001-4400	C-2	H-2	3748.95	3601-4000	C-3
D-4	3692.75	3601-4000	C-3	H-3	3704.92	3601-4000	C-3
E-1	3956.11	3601-4000	C-3	H-4	2983.21	2800-3200	C-5

As clearly shown on table 5-44, the column grouped in to five groups based on their base axial force; C-1 for axial force ranges between 4401 to 4800 KN, C-2 for axial force ranges between 4001 to 4400 KN, C-3 for axial force ranges between 3601 to 4000 KN, C-4 for axial force ranges between 3201 to 3600 KN and C-5 for axial force ranges between 2800 to 3200 KN. In the interval the maximum axial force is taken for foundation design as shown in the table below.

Table C.45 Maximum axial force in each column group for G+7 with C-25 concrete

Interval	P_{max} (KN)	Location of P_{max}	Group	No Member
2800-3200	3032.91	H-1	C-5	2
3201-3600	3581.48	G-1	C-4	3
3601-4000	3970.64	A-2	C-3	13
4001-4400	4356.94	D-3	C-2	9
4401-4800	4627.1	E-3	C-1	3

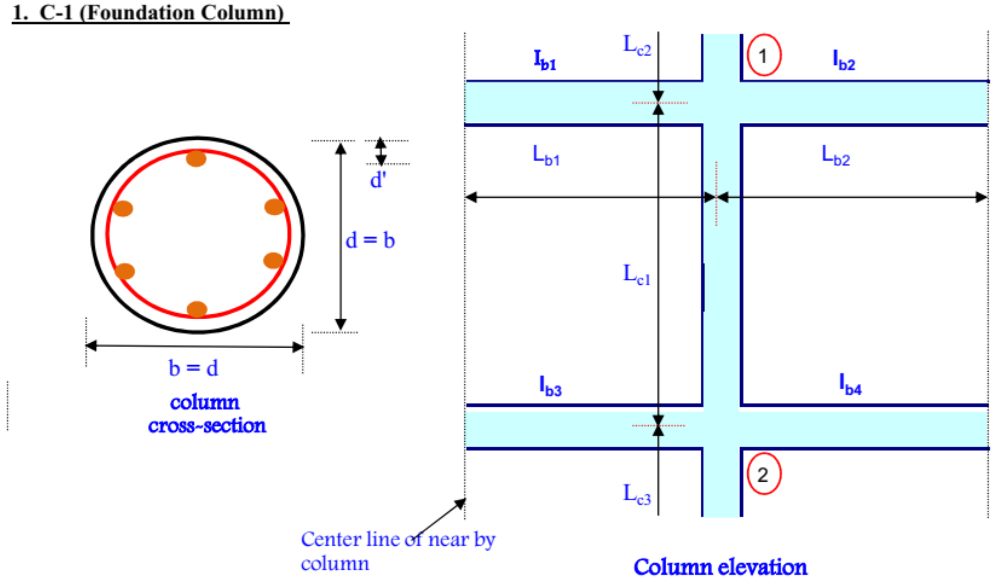
DESIGN OF CIRCULAR COLUMN BASED ON ES EN:2015

SAMPLE COLUMN DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building **Date:** 23-May-18

Description: Design of Column for G+7 Building (C-25) **Design by:** Yohannes Sefiw

1. C-1 (Foundation Column)



2. Material constant

Concrete - Grade C- 25 Steel - Grade S- 300

f_{ck}	20000	kpa	$f_{ck} = 0.8f_{cu}$	F_{yk}	300000	kpa
f_{ctk}	1547.2932	kpa	$f_{ctk} = 0.21f_{ck}^{2/3}$	γs	1.15	
γc	1.5			F_{yd}	260,870	kpa
f_{cd}	11333.333	kpa	$f_{cd} = 0.85f_{ck}/\gamma_c$	E_s	200,000	kpa
f_{ctd}	1031.5288	kpa	$f_{ctd}=f_{ctk}/\gamma_c$	$A_{s\ (min)}$	0.0027	m^2
E_{cm}	28847.595	kpa	$E_{cm} = 9.5(f_{ck}+8)^{1/3}$	$A_{s\ (max)}$	0.026533	m^2

3. Analysis Result:

Axial (kN)	Mom. x-x	Mom y-y
4627.10	-169.36	-5.80
4578.26	480.26	7.59

4. Structure Classification:

Second-order global elastic analysis was done. Therefore both sway and non-sway are taken care of.

5. Dimensions in x-x direction:

Item	Depth	Width
B_1 =	0.45	0.30
B_2 =	0.45	0.30
B_3 =	0.45	0.30
B_4 =	0.45	0.30
C_1 =	0.65	0.65
C_2 =	0.65	0.65
C_3 =	0.65	0.65

L_{b1} =	5.50
L_{b2} =	6.00
L_{c1} =	3.20
L_{c2} =	3.20
L_{c3} =	1.50

6. Dimensions in y-y direction:

Item	Depth	Width
B_1 =	0.45	0.30
B_2 =	0.45	0.30
B_3 =	0.45	0.30
B_4 =	0.45	0.30
C_1 =	0.65	0.65
C_2 =	0.65	0.65
C_3 =	0.65	0.65

L_{b1} =	6.00
L_{b2} =	6.00
L_{c1} =	3.20
L_{c2} =	3.20
L_{c3} =	1.50

7. Limits of Slenderness:

$$\lambda \leq 50 - 25\left(\frac{M_1}{M_2}\right) \qquad \frac{M_1}{M_2} = \underline{-0.35} \qquad \frac{M_1}{M_2} = \underline{-0.76}$$

$$\lambda \leq \underline{58.82} \qquad \lambda \leq \underline{69.10}$$

But, the slenderness ratio is:

$$\lambda = \frac{L_e}{i} \qquad i = \text{Radius of gyration} = \sqrt{\frac{I_g}{A_g}}$$

A_g = 0.332 m^2

I_g = 0.00876 m^4

i = 0.163

L_e = Effective buckling length

8. Effective Buckling Length:

$$L_e = \frac{\alpha_m + 0.4}{\alpha_m + 0.8} L \geq 0.7L$$

$$\alpha_m = \frac{\alpha_1 + \alpha_2}{2}$$

$$\alpha_1 = \frac{I_{c1}/L_{c1} + I_{c2}/L_{c2}}{I_{b1}/L_{b1} + I_{b2}/L_{b2}}$$

$$\alpha_2 = \frac{I_{c1}/L_{c1} + I_{c3}/L_{c3}}{I_{b3}/L_{b3} + I_{b4}/L_{b4}}$$

About x-x direction.				About y-y direction.			
I_{c1} =	0.00876	I_{c1} =	0.00876	I_{c1} =	0.00876	I_{c1} =	0.00876
I_{c2} =	0.00876	I_{c3} =	0.00876	I_{c2} =	0.00876	I_{c3} =	0.00876
I_{b1} =	0.00228	I_{b3} =	0.00228	I_{b1} =	0.00228	I_{b3} =	0.00228
I_{b2} =	0.00228	I_{b4} =	0.00228	I_{b2} =	0.00228	I_{b4} =	0.00228
α_1 =	**6.895**	α_2 =	**10.802**	α_1 =	**7.208**	α_2 =	**11.293**
	α_m =	**8.848**			α_m =	**9.251**	

- the effective buckling length:

L_e = **3.067** $\qquad$ L_e = **3.073**

- Slenderness ratio:

Ì = **18.876** **Not Slender** **Ignore Secondary Effects** | Ì = **18.909** **Not Slender** **Ignore Secondary Effect**

9. Design Actions:

Calculate Eccentricities in the x-x Direction

$$\text{Total} = e_{tot} = e_e + e_a + e_2$$

$$e_e = \text{max of} \begin{cases} 0.6e_{02} + 0.4e_{01} \\ 0.4e_{02} \end{cases}$$

e_{01} = -0.0366

e_{02} = 0.1049

e_e = **0.0483** m

$$e_a = \frac{L_e}{300} \geq 200mm$$

e_a = **0.02** m

e_2 = **0.00** m

e_{tot} = **0.0683** m

N_{sd} = **4627.10** kN

$M_{sd\ x\text{-}x}$ = **316.03** kN-m

Calculate Eccentricities in the y-y Direction

$$\text{Total} = e_{tot} = e_e + e_a + e_2$$

$$e_e = \text{max of} \begin{cases} 0.6e_{02} + 0.4e_{01} \\ 0.4e_{02} \end{cases}$$

e_{01} = -0.0013

e_{02} = 0.0017

e_e = **0.0007**

$$e_a = \frac{L_e}{300} \geq 200mm$$

e_a = **0.02** m

e_2 = **0.00** m

e_{tot} = **0.0207** m

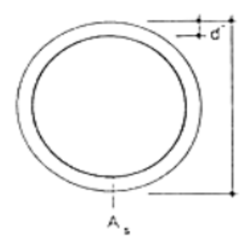
$M_{sd\ y\text{-}y}$ = **95.61** kN-m

10. Reinforcement Calculation:

10.1 Axial Reinforcement

d'/h = 0.1 e_{yd} = 0.002 Use - **Uiaxial Chart No. 12**

$$\upsilon_{sd} = \frac{N_{sd}}{f_{cd} A_c} \qquad \mu_{sd,x-x} = \frac{M_{sd,x-x}}{f_{cd} A_c h} \qquad \mu_{sd,y-y} = \frac{M_{sd,y-y}}{f_{cd} A_c b}$$



v_{sd} = **1.231** $\mu_{sd,x\text{-}x}$ = **0.129** $\mu_{sd,y\text{-}y}$ = **0.039**

μ_{sd} = **0.129** μ_{sd} = Max ($\mu_{sd,x\text{-}x}$, $\mu_{sd,y\text{-}y}$)

ώ = **0.65**

$$A_{s,tot} = \frac{\omega A_c f_{cd}}{f_{yd}}$$

$A_{s,\ min} < A_{s,\ prv} < A_{s,\ max}$

$A_{s,\ prv}$ = Max ($A_{s,\ min}$, $A_{s,\ tot}$)

$A_{s,\ tot}$ = **0.0093658** m^2 $A_{s,\ prv}$ = **0.00937** m^2

$Ø_m$ = **24**

No Bars= **20.71**

Use 21 Ø 24

10.2 Check bar Congestion per layer

Max Aggregate Size, S (mm) = **2.00**

$$n_{max} = \frac{\Pi(D - 2C - 2Øs)}{Øm + S}$$

Cover, C (mm) = **25.00**

Max No Bars, n_{max} = **71** Status - **Ok! No bar congestion**

10.3 Shear Reinforcement

$V_{Rd} = 0.25f_{cd}bd > V_{sd}$ $V_c = 0.25f_{ctd}K_1K_2bd$ $K_1 = 1+50\rho < 2$ $k_2 = 1.6 - d > 1$

$\rho = As/bd$ $S_{cal} = A_vf_{yd}d/V_s$ $V_s = V_{sd} - V_c$ $A_v = 2a_s$

S_{max} = min [$12Ø_m$, b, 300mm]

V_{RD} (KN)	Status	V_{sdx} (KN)	V_{sdy} (KN)
1197.08	Ok!	118.43	124.15
K_1	K_2	V_c (KN)	
2.00	1.00	217.91	
Φ (mm)	S_{max} (mm)	S_{cal} (mm)	S_{prv} (mm)
8	280	280	280

Use Ø 8 C/C 280 mm

Figure C.29 Sample column design for G+7 building C-25 concrete

C.5.1.2.5 SAMPLE FOUNDATION DESIGN FOR G+7 BUILDING WITH C-25 CONCRETE

Following similar procedure as sample foundation design of G+2 building, sample foundation design for G+7 building is done as shown below.

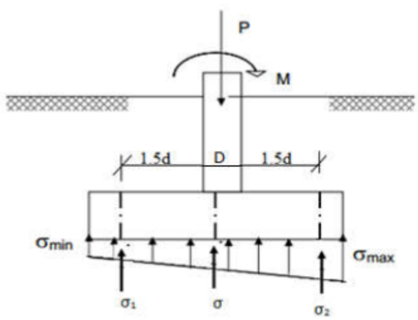
DESIGN OF SQUARE ISOLATED FOUNDATION BASED ON ES EN:2015

SAMPLE FOUNDATION DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building Date: 26-May-18

Description: Design of Square Isolated Foundation for G+7 Building (C-25) Design by: Yohannes Sefiw

1. Foundation 1 (F-1)



2. Material Constant

Concrete Grade C- 25 Steel Grade S- 300

f_{ck} = 20,000.000000 kpa f_{yk} = 300,000.0000 Kpa

f_{ctk} = 1,547.293229 kpa γs = 1.15

γc = 1.50 f_{yd} = 260,869.5652 Kpa

f_{cd} = 11,333.333333 kpa E_s = 200,000.0000 Kpa

f_{ctd} = 1,031.528820 kpa Cover, C (mm) = 50

E_{cm} = 28,847.595233 kpa

3. Soil Property

Ground Type - Dense sand

Facter of Safety, Fs = 2.00

$\sigma_{ult} = F_s \cdot \sigma_{al}$ Allowble soil bearing capacity, σ_{all} = 420 Kpa

Ultimate Soil bearing capacity, σ_{ult} = 840 kpa

4. Proportioning

$A = B^2 = P/\sigma_{all,}$ $B = \sqrt{P/\sigma all}$ Axial force, P (KN) = 4627.10 Foundation Width, B (m) = 3.32

Provided Foundation Width, B (m) = 3.35

5. Contact pressure

$\sigma_{max} = \frac{P}{A}\left(1+6\frac{e_x}{B}+6\frac{e_y}{B}\right) \leq \sigma_{ult}$ $\sigma_{min} = \frac{P}{A}\left(1-6\frac{e_x}{B}-6\frac{e_y}{B}\right)$ $e_x = \frac{M_x}{P}$ $e_y = \frac{M_y}{P}$

M_x (KNm) = 489.84 e_x (m) = 0.1059 σ_{max} (Kpa) = 567.13 Area, A(m^2) = 11.2225

M_y (KNm) = 480.26 e_y (m) = 0.1038 σ_{min} (Kpa) = 257.48 **Status -** **Ok! Area is adequate**

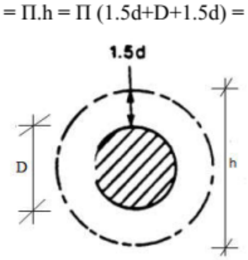
6. Foundation Thickness

Thickness, d (m) = 0.90 Column Diameter, D (m) = 0.65

6.1 Check trial foundation thickness for punching shear

The punching shear resistance, $V_{Rd1} = 0.25 f_{ctd} \cdot K1 \cdot K2 \cdot U \cdot d$, $K_1 = 1+50\rho \leq 2$ $K_2 = 1.6 - d \geq 1$

$U = \Pi.h = \Pi(1.5d+D+1.5d) = \Pi(3d+D)$ For circular column Developed shear, $V_1 = \sigma A$, $\sigma = \frac{\sigma 1+\sigma 2}{2}$



$\sigma_1 = \sigma_{min} + \frac{\left(\frac{B-3d-D}{2}\right)(\sigma_{max}-\sigma_{min})}{B}$ $\sigma_2 = \sigma_{min} + \frac{\left(\frac{B+3d+D}{2}\right)(\sigma_{max}-\sigma_{min})}{B}$

Net developed shear, $V_{d1} = P - V_1$ $\rho_{min} = 0.5/f_{yk}$ $A = \frac{\Pi}{4}(3d+D)^2$

The thickness is sufficient for punching shear if $V_{Rd1} > V_{d1}$ A (m^2) = 8.810

ρ_{min} = 0.0017 K_2 = 1.00 V_{Rd1} (KN) = 2646.19 V_{d1} (KN) = 994.83

U (m) = 10.52 K_1 = 1.08 V_1 (KN) = 3632.27

σ_1 (Kpa) = 257.48 σ_2 (Kpa) = 567.128 σ (Kpa) = 412.306

Status - **Ok! Thickness is adequate for punching shear**

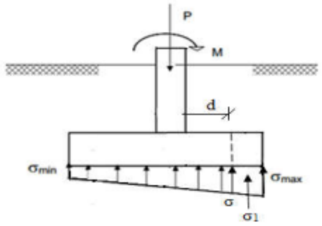
6.2 Check trial foundation thickness for wide beam shear

The wide beam shear resistance, $V_{Rd2} = 0.25f_{ctd}k_1k_2bd$

The thickness is sufficient for wide beam shear if $V_{Rd2} > V_{d2}$

Developed wide beam shear, $V_{d2} = \sigma_1 A$, $\sigma_1 = \frac{\sigma + \sigma max}{2}$

$A = B\frac{B-D-2d}{2}$ $\sigma = \sigma_{min} + \frac{(\frac{B+2d+D}{2})(\sigma_{max}-\sigma_{min})}{B}$



V_{Rd2} (KN) = **842.31**

V_{d2} (KN) = **823.59**

σ (Kpa) = 525.534 σ_1 (Kpa) = 546.331 A (m^2) = 1.51

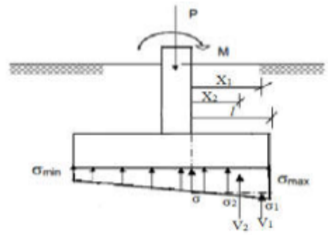
Status - Ok! Thickness is adequate for wide beam shear

6.3. Check trial foundation thickness for bending moment

Developed moment, $M_{sd} = \sum\sigma.A.x = V_1X_1 + V_2X_2$ $V_1 = \sigma_1 l$ $V_2 = \sigma_2 l$

$l = \frac{1}{2}(B-D)$ $X_2 = \frac{1}{2}l$ $X_1 = \frac{2}{3}l$ $\sigma = \sigma_{min} + \frac{(\frac{B+D}{2})(\sigma_{max}-\sigma_{min})}{B}$

The concrete moment capacity, $M = 0.32f_{cd}bd^2$ $\sigma_1 = \frac{\sigma_{max}-\sigma}{2}$



l = 1.35 X_2 = 0.675 X_1 = 0.900 $\sigma_2 = \sigma$

σ (Kpa) = 442.346 σ_1 (Kpa) = 62.391 σ_2 (Kpa) = 442.346

V_1 (KN/m) = 84.2279 V_2 (KN/m) = 597.167 M_{sd} (KN-m/m) = **478.893**

M (KN-m/m) = **2937.60**

Status - Ok! The thickness is adequate for bending moment

7. Reinforcement Calculation

$A_s = \rho bd$ $\rho = \frac{fcd}{fyd}\left[1-\sqrt{1-\frac{2Msd}{fcdbd^2}}\right]\rho_{min}$ Spacing, $S = \frac{bas}{As}$

ρ = 0.0023 A_s (mm^2) = **2095.9** **Ø = 20** S (mm) = **149.816**

Use

Ø	20	C/C	140	mm

8. Development length

$l_d = \frac{\phi fyd}{4fbd}$ $f_{bd} = f_{ctd}$

l_d (mm) = **1264.5** $l = \frac{B-D}{2}$ - Cover $l_{d, avl}$ (mm) = **1300**

Status - Bend the bars upward is not mandatory!

Figure C.30 Sample foundation design for G+7 building with C-25 concrete

C.5.1.3 SAMPLE STRUCTURAL DESIGN FOR G+12 BUILDING WITH C-25 CONCRETE

C.5.1.3.1 SAMPLE SLAB DESIGN FOR G+12 BUILDING WITH C-25 CONCRETE

Following similar procedure as sample design of slab for G+2 building, sample slab design for G+12 building is done as shown below.

Table C.46 Sample slab design for G+12 building using C-25 concrete

DESIGN OF TWO WAY SOLID SLAB BASED ON ES EN:2015

SAMPLE SLAB DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building **Date:** 18-May-18

Description: Analysis & Design of Slab for G+12 building **Design by:** Yohannes Sefiw

1 Material Constant

Concrete Grade (f_{cu})	25	Design Material Strength (mpa)	
R.Steel Grade (f_{yk})	300	f_{cd}	11.33
Cover [mm]	15	f_{yd}	260.87

β_a for 2:1	β_a for 1:1	L_y/L_x	β_a
35.00	45.00	1.09	44.09

2 Depth Determination

Panel Name	FS-9		d_{eff} required [mm]	D required [mm]	D provided [mm]
Depth	L_x [m]	L_y [m]			
	5.50	6.00	106.03	130.00	200

3 Total Load calculation

Description	Thickness t	Unit weight	Load
Slab	0.20	25	5.00
Floor finish	0.02	27	0.54
Ceiling Plaster	0.02	23	0.46
Cement Screed	0.03	23	0.69
Partition Wall	0.10	14	0.80
		Total Dead Load gk (KN/m^2)	7.49
		Live Load qk (KN/m^2	3
		Design load P_d (KN/m^2)	**14.61**

Partial safety factor	
γ_{DL}	1.35
γ_{LL}	1.50

Wall Description	
Height (m)	3.05
Length (m)	5.50

4 Total Moment calculation

ρ values	ρ_1	ρ_2	ρ_3	ρ_4	n_d
	1.333	1.333	1.333	1.333	0.000
Moment Coefficent	α_{xs}	α_{ys}	α_{xs}	α_{ys}	β
	0.037	0.032	0.028	0.024	0.26
Moment (KN-m/m)	M_{xs}	M_{ys}	M_{xf}	M_{yf}	
	16.35	14.14	12.37	10.60	

5 Reinforcement Calculation

k-value	500	440	380	330
ρ	0.20	0.17	0.15	0.13
A_{min}[mm^2]	302	302	302	302
As_{req} [mm^2]	354	305	267	228
As_{prv} [mm^2]	354	305	302	302
Ø (mm)	8	8	8	8
No of Bars/panel	44	35	39	35
S_{max} [mm]	350	350	350	350
S_{Cal}[mm]	140.00	160.00	160.00	160.00
S_{prv} [mm]	140.00	160.00	160.00	160.00

Wall on beam TS

Length of wall (m)	5.50
Length of beam (m)	5.50
Wall Thickness (m)	0.004
Hieght of wall (m)	2.85
γ(KN/m^3)	27.00
Gk (KN/m)	0.31

6 Total Un-factor Load transfer to beams

	Load Transfer on Beams			L_y/L_x = 1.09
Shear coeffcient	V_{bxc}	V_{bxd}	V_{byc}	V_{byd}
	0.361	0.000	0.330	0.000
Load on Beams	R_{cx}	R_{dx}	R_{cy}	R_{dy}
Total design load	20.81	N.A.	19.03	N.A.
Live Load	5.95	N.A.	5.45	N.A.
Dead Load	14.85	N.A.	13.59	N.A.

Note:- N.A.-Means Not Applicable — 1 -Continuous

input data — 0 -Discontinous

Wall on beam BS

Length of wall (m)	5.50
Length of beam (m)	5.50
Wall Thickness (m)	0.004
Hieght of wall (m)	2.85
γ(KN/m^3)	27.00
Gk (KN/m)	0.31

Wall on beam LS

Length of wall (m)	6.00
Length of beam (m)	6.00
Wall Thickness (m)	0.10
Hieght of wall (m)	2.85
γ(KN/m^3)	14.00
Gk (KN/m)	3.99

Wall on beam RS

Length of wall (m)	6.00
Length of beam (m)	6.00
Wall Thickness (m)	0.10
Hieght of wall (m)	2.85
γ(KN/m^3)	14.00
Gk (KN/m)	3.99

C.5.1.3.2 SAMPLE STAIRCASE DESIGN FOR G+12BUILDING WITH C-25 CONCRETE

The design value of staircase for G+12 building is the same as design value of staircase for G+2 building because of the architectural plan, staircase layout, height of riser, width of tread, staircase loading and other necessary parameters are the same with G+2 building.

C.5.1.3.3 SAMPLE BEAM DESIGN FOR G+12 BUILDING WITH C-25 CONCRETE

Following similar procedure as sample beam design of for G+2 building, sample beam design for G+12 building is done as shown below.

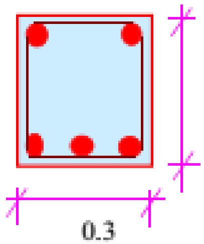
DESIGN OF BEAM BASED ON ES EN:2015

SAMPLE BEAM DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building   Date: 19-May-18

Description: Design of Beam for G+12 building with C-25 concrete   Design by: Yohannes Sefiw

1. First floor beam (on axis B span 2-1)



Depth	0.50	m
Width	0.30	m
$Ø_m$	0.02	m
Cover	0.025	m

2. Effective depth calculation

d_{eff} = D - Cover - $Ø_m/2$ - $Ø_s$

d_{eff} = 0.457 m

3. Depth for defflection

$L_{e\,(m)}$ = 6.00

β_a = 28.00

$$d \geq (0.4 + \frac{f_{yk}}{400})\frac{L_e}{\beta_a}$$

d (m) = 0.246 **OK!**

4. Design bending moment and shear force

Design Negative Moment Mu = 170.40 kN-m

Design Positive Moment Mu = 90.76 kN-m

Design Shear Force, Vsd = 145.46 KN

5. Material constant

Concrete Grade C- 25

f_{ck} = 20,000 kpa

f_{ctk} = 1,547 kpa

γc = 1.5

f_{cd} = 11,333 kpa

f_{ctd} = 1,032 kpa

E_{cm} = 28,848 kpa

$f_{ck} = 0.8 f_{cu}$

$f_{ctk} = 0.21 f_{ck}^{2/3}$

$f_{cd} = 0.85 f_{ck}/\gamma_c$

$f_{ctd} = f_{ctk}/\gamma_c$

$E_{cm} = 9.5(f_{ck}+8)^{1/3}$

$f_{yd} = f_{yk}/\gamma_s$

$\rho_{min} = \frac{0.6}{f_k}$

Steel Grade S- 300

fyk = 300,000.0 kpa

γs = 1.15

fyd = 260869.57 kpa

Es = 200000.00 kpa

ρ_{min} = 0.002

ρ_{max} = 0.04

6. Design for flexure

$$\rho_{req} = \frac{1}{m}\left[1 - \sqrt{1 - \frac{2m_u}{f_{cd}bd^2}}\right] \qquad m = \frac{f_{yd}}{f_{cd}} \qquad \mu = \frac{M_u}{f_{cd}bd^2}$$

ρ = Max(ρ_{req}, ρ_{min})

As = ρbd

Negative Reinforcement	**Positive Reinforcement**
m = 23.02	m = 23.02
μ = 0.240	μ = 0.128
Check Ducklity - **OK!**	Check Ducklity - **OK!**
Beam Type - **Single Reinforced!**	Beam Type - **Single Reinforced!**
ρ_{req} = 0.0121	ρ_{req} = 0.0060

$As_1 = 0.00166\ m^2$ $As_1 = 0.00082\ m^2$

$As_2 = 0.00000\ m^2$ $As_2 = 0.00000\ m^2$

$Ø_m = 20$ $Ø_m = 16$

$n_1 = 5.29$ $n_1 = 4.07$

$n_2 = 0.00$ $n_2 = 0.00$

Use **6 Ø 20** Use **5 Ø 16**

$As_{prvd} = 0.00188$ $As_{prvd} = 0.0010$

Capacity = 189.16 KN-m Capacity = 109.74

Reserve = 9.92% Reserve = 17.29%

7. Design for Shear

$V_{Rd} = 0.25\, fcd\, b_w\, d > V_{sd}$ $V_{Rd} = 323.71$ KN Check Shear Resistance - **OK!**

$V_c = 0.25\, f_{cd}\, k_1 k_2 b_w d$ $V_s = 77.27$ KN

$K1 = 1+50\rho < 2$ $k_1 = 1.687$

$k_2 = 1.6 - d > 1$ $k_2 = 1.143$

$\rho = As/bd$

$V_c = 68.19$ KN

Shear Reinforcement

$$s = \frac{A_v d f_{yd}}{V_s}$$

$V_s = V_{sd} - V_c$

$A_v = 0.00010$

$Ø_s = 8$

$S_{max} = 228.5$ mm

$S_{cal} = 155.1$ mm

$S_{prv} = 150$ mm

$S_{max} = 0.5d < 300mm$ for $2/3V_{RD} > V_{sd}$

$S_{max} = 0.3d < 200mm$ for $2/3V_{RD} < V_{sd}$

$S_{prv} = Min\ (S_{cal}, S_{max})$

Use **Ø 8 C/C 150 mm**

Figure C.31 Sample beam design for G+12 building with C-25

C.5.1.3.4 SAMPLE COLUMN DESIGN FOR G+12 BUILDING WITH C-25 CONCRETE

Following similar procedure as sample column design of G+2 building, sample column design for G+12 building is done as shown below.

Table C.47 Column grouping for G+12 building with C-25 concrete

Axis	P (KN)	Interval	Group	Axis	P (KN)	Interval	Group
A-2	7437.71	6901-7500	C-3	E-2	7902.34	7501-8100	C-2
A-3	7471.56	6901-7500	C-3	E-3	8509.75	> 8100	C-1
B-1	7242.9	6901-7500	C-3	E-4	7375.1	6901-7500	C-3
B-2	7576.75	7501-8100	C-2	F-1	7583.49	7501-8100	C-2
B-3	7668.5	7501-8100	C-2	F-2	8760.95	> 8100	C-1
B-4	7227.17	6901-7500	C-3	F-3	8363.33	> 8100	C-1
C-1	6900.87	6901-7500	C-3	F-4	7041.93	6901-7500	C-3
C-2	7772.17	7501-8100	C-2	G-1	6759.48	6301-6900	C-4
C-3	7676.39	7501-8100	C-2	G-2	8355.85	> 8100	C-1
C-4	6738.9	6301-6900	C-4	G-3	8262.63	> 8100	C-1
D-1	6758.48	6301-6900	C-4	G-4	6600.55	6301-6900	C-4
D-2	7300.59	6901-7500	C-3	H-1	5813.58	5700-6300	C-5
D-3	8060.2	7501-8100	C-2	H-2	7016.29	6901-7500	C-3
D-4	6987.44	6901-7500	C-3	H-3	6928.81	6901-7500	C-3
E-1	7293.81	6901-7500	C-3	H-4	5707.88	5700-6300	C-5

As clearly shown on table 5-47, the column grouped in to five groups based on their base axial force; C-1 for axial force greater than 8100 KN, C-2 for axial force ranges between 7501 to 8100 KN, C-3 for axial force ranges between 6901 to 7500 KN, C-4 for axial force ranges between 6301 to 3900 KN and C-5 for axial force ranges between 5700 to 6300 KN. In the interval the maximum axial force is taken for foundation design as shown in the table below.

Table C.48 Maximum axial force in each column group for G+12 with C-25 concrete

Interval	P_{max} (KN)	Location of P_{max}	Group	No Member
5700-6300	5813.58	H-1	C-5	2
63001-6900	6759.48	G-1	C-4	4
6901-7500	7576.75	B-2	C-3	12
7501-8100	8060.2	D-3	C-2	7
> 8100	8760.95	F-2	C-1	5

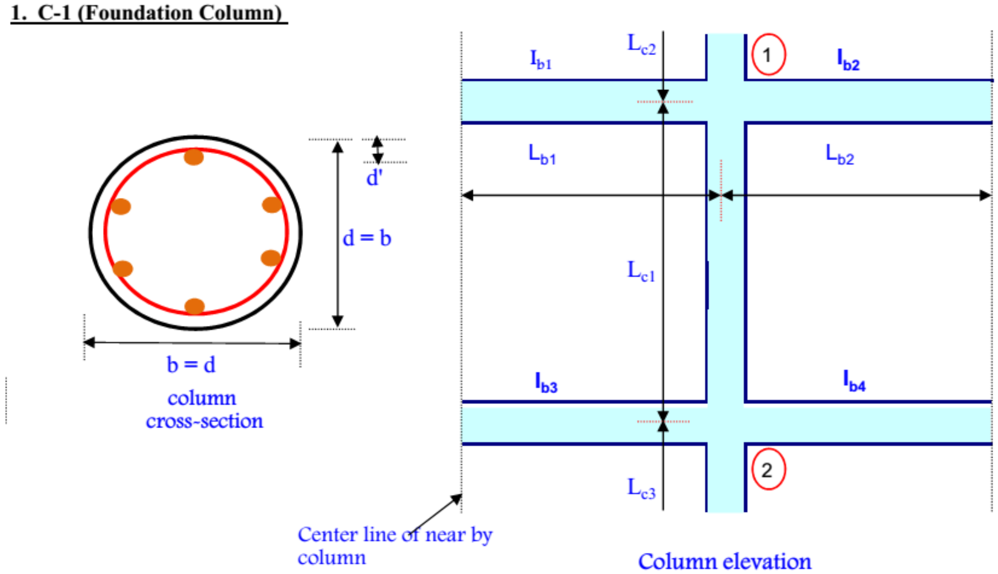
DESIGN OF CIRCULAR COLUMN BASED ON ES EN:2015

SAMPLE COLUMN DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building **Date:** 23-May-18

Description: Design of Column for G+12 Building (C-25) **Design by:** Yohannes Sefiw

1. C-1 (Foundation Column)



2. Material constant

Concrete - Grade C- 25 Steel - Grade S- 300

f_{ck}	20000	kpa	$f_{ck} = 0.8 f_{cu}$	F_{yk}	300000	kpa
f_{ctk}	1547.2932	kpa	$f_{ctk} = 0.21 f_{ck}^{2/3}$	γs	1.15	
γc	1.5			F_{yd}	260,870	kpa
f_{cd}	11333.333	kpa	$f_{cd} = 0.85 f_{ck}/\gamma_c$	E_s	200,000	kpa
f_{ctd}	1031.5288	kpa	$f_{ctd} = f_{ctk}/\gamma_c$	$A_{s\,(min)}$	0.0045	m^2
E_{cm}	28847.595	kpa	$E_{cm} = 9.5(f_{ck}+8)^{1/3}$	$A_{s\,(max)}$	0.045373	m^2

3. Analysis Result:

Axial (kN)	Mom. x-x	Mom y-y
8760.95	503.39	589.59
8667.44	942.57	1001.71

4. Structure Classification:

Second-order global elastic analysis was done. Therefore both sway and non-sway are taken care of.

5. Dimensions in x-x direction:

Item	Depth	Width
B_1 =	0.50	0.30
B_2 =	0.50	0.30
B_3 =	0.50	0.30
B_4 =	0.50	0.30
C_1 =	0.85	0.85
C_2 =	0.85	0.85
C_3 =	0.85	0.85

L_{b1} =	5.50
L_{b2} =	6.00
L_{c1} =	3.20
L_{c2} =	3.20
L_{c3} =	1.50

6. Dimensions in y-y direction:

Item	Depth	Width
B_1 =	0.50	0.30
B_2 =	0.50	0.30
B_3 =	0.50	0.30
B_4 =	0.50	0.30
C_1 =	0.85	0.85
C_2 =	0.85	0.85
C_3 =	0.85	0.85

L_{b1} =	6.00
L_{b2} =	6.00
L_{c1} =	3.20
L_{c2} =	3.20
L_{c3} =	1.50

7. Limits of Slenderness:

$$\lambda \le 50 - 25\left(\frac{M_1}{M_2}\right)$$

$\frac{M_1}{M_2} = 0.53$ $\qquad$ $\frac{M_1}{M_2} = 0.59$

$\lambda \le 36.65$ $\qquad$ $\lambda \le 35.29$

But, the slenderness ratio is:

$$\grave{\imath} = \frac{L_e}{i} \qquad i = \text{Radius of gyration} = \sqrt{\frac{I_g}{A_g}}$$

A_g = 0.567 m^2

I_g = 0.02561 m^4

i = 0.213

L_e = Effective buckling length

8. Effective Buckling Length:

$$L_e = \frac{\alpha_m + 0.4}{\alpha_m + 0.8} L \ge 0.7L$$

$$\alpha_m = \frac{\alpha_1 + \alpha_2}{2}$$

$$\alpha_1 = \frac{I_{c1}/L_{c1} + I_{c2}/L_{c2}}{I_{b1}/L_{b1} + I_{b2}/L_{b2}}$$

$$\alpha_2 = \frac{I_{c1}/L_{c1} + I_{c3}/L_{c3}}{I_{b3}/L_{b3} + I_{b4}/L_{b4}}$$

About x-x direction.				About y-y direction.			
I_{c1} =	0.02561	I_{c1} =	0.02561	I_{c1} =	0.02561	I_{c1} =	0.02561
I_{c2} =	0.02561	I_{c3} =	0.02561	I_{c2} =	0.02561	I_{c3} =	0.02561
I_{b1} =	0.00313	I_{b3} =	0.00313	I_{b1} =	0.00313	I_{b3} =	0.00313
I_{b2} =	0.00313	I_{b4} =	0.00313	I_{b2} =	0.00313	I_{b4} =	0.00313
α_1 =	**14.698**	α_2 =	**23.028**	α_1 =	**15.367**	α_2 =	**24.074**
	α_m =	**18.863**			α_m =	**19.720**	

- the effective buckling length:

L_e = **3.135** $\qquad$ L_e = **3.138**

- Slenderness ratio:

ì = **14.752** **Not Slender** **Ignore Secondary Effects** ì = **14.765** **Not Slender** **Ignore Secondary Effect**

9. Design Actions:

Calculate Eccentricities in the x-x Direction

$$\text{Total} = e_{tot} = e_e + e_a + e_2$$

$$e_e = \text{max of} \begin{cases} 0.6e_{02} + 0.4e_{01} \\ 0.4e_{02} \end{cases}$$

$e_{01} = 0.0575$

$e_{02} = 0.1087$

$e_e =$ **0.0882** m

$$e_a = \frac{L_e}{300} \geq 200mm$$

$e_a =$ **0.02** m

$e_2 =$ **0.00** m

$e_{tot} =$ **0.1082** m

$N_{sd} =$ **8760.95** kN

$M_{sd\ x\text{-}x} =$ **948.22** kN-m

Calculate Eccentricities in the y-y Direction

$$\text{Total} = e_{tot} = e_e + e_a + e_2$$

$$e_e = \text{max of} \begin{cases} 0.6e_{02} + 0.4e_{01} \\ 0.4e_{02} \end{cases}$$

$e_{01} = 0.0673$

$e_{02} = 0.1156$

$e_e =$ **0.0963**

$$e_a = \frac{L_e}{300} \geq 200mm$$

$e_a =$ **0.02** m

$e_2 =$ **0.00** m

$e_{tot} =$ **0.1163** m

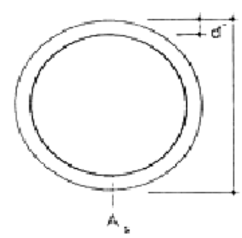
$M_{sd\ y\text{-}y} =$ **1018.57** kN-m

10. Reinforcement Calculation:

10.1 Axial Reinforcement

$d'/h = 0.1$ $e_{yd} = 0.002$ Use - **Uiaxial Chart No. 12**

$$\upsilon_{sd} = \frac{N_{sd}}{f_{cd} A_c} \qquad \mu_{sd,x-x} = \frac{M_{sd,x-x}}{f_{cd} A_c h} \qquad \mu_{sd,y-y} = \frac{M_{sd,y-y}}{f_{cd} A_c b}$$



$v_{sd} =$ **1.363** $\mu_{sd,x\text{-}x} = 0.174$ $\mu_{sd,y\text{-}y} = 0.186$

$\mu_{sd} =$ **0.186** $\mu_{sd} = \text{Max}(\mu_{sd,x\text{-}x}, \mu_{sd,y\text{-}y})$

$\acute{\omega} =$ **1.04**

$$A_{s,tot} = \frac{\omega A_c f_{cd}}{f_{yd}}$$

$A_{s,\min} < A_{s,prv} < A_{s,\max}$

$A_{s,prv} = \text{Max}(A_{s,\min}, A_{s,tot})$

$A_{s,tot} =$ **0.0256257** m^2 $A_{s,prv} =$ **0.02563** m^2

$Ø_m =$ 32

No Bars = **31.88**

Use 32 Ø 32

10.2 Check bar Congestion per layer

$$n_{max} = \frac{\Pi(D - 2C - 2Øs)}{Øm + S}$$

Cover, C (mm) = 25.00

Max Aggregate Size, S (mm) = 2.00

Max No Bars, n_{max} = 73

Status - **Ok! No bar congestion**

10.3 Shear Reinforcement

$V_{Rd} = 0.25f_{cd}bd > V_{sd}$ $V_c = 0.25f_{ctd}K_1K_2bd$ $K_1 = 1+50\rho < 2$ $k_2 = 1.6 - d > 1$

$\rho = As/bd$ $S_{cal} = A_v f_{yd} d/V_s$ $V_s = V_{sd} - V_c$ $A_v = 2a_s$

V_{RD} (KN)	Status	V_{sdx} (KN)	V_{sdy} (KN)
2047.08	**Ok!**	178.11	179.68
K_1	K_2	V_c (KN)	
2.00	1.00	372.64	
$Ø_s$	S_{max} (mm)	S_{cal} (mm)	S_{prv} (mm)
8	300	300	300

Use **Ø 8 C/C 300 mm**

Figure C.32 Sample column design for G+12 building C-25 concrete

C.5.1.3.5 SAMPLE FOUNDATION DESIGN FOR G+12 BUILDING WITH C-25 CONCRETE

Following similar procedure as sample foundation design of G+2 building, sample foundation design for G+12 building is done as shown below.

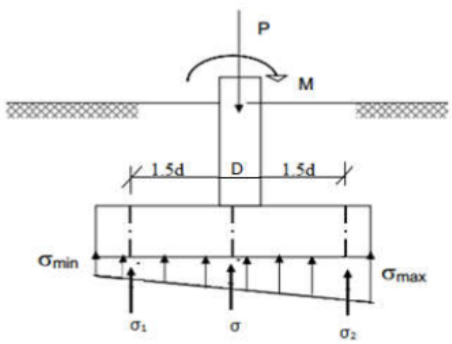
DESIGN OF SQUARE ISOLATED FOUNDATION BASED ON ES EN:2015

SAMPLE FOUNDATION DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building Date: 26-May-18

Description: Design of Square Isolated Foundation for G+12 Building Design by: Yohannes Sefiw

1. Foundation 1 (F-1)



2. Material Constant

Concrete Grade C- 25 Steel Grade S- 300

f_{ck} = 20,000.000000 kpa f_{yk} = 300,000.0000 Kpa

f_{ctk} = 1,547.293229 kpa γs = 1.15

γc = 1.50 f_{yd} = 260,869.5652 Kpa

f_{cd} = 11,333.333333 kpa E_s = 200,000.0000 Kpa

f_{ctd} = 1,031.528820 kpa Cover, C (mm) = 50

E_{cm} = 28,847.595233 kpa

3. Soil Property

Ground Type - Dense sand

Facter of Safety, Fs = 2.00

$\sigma_{ult} = F_s . \sigma_{al}$ Allowble soil bearing capacity, σ_{all} = 420 Kpa

Ultimate Soil bearing capacity, σ_{ult} = **840** kpa

4. Proportioning

$A = B^2 = P/\sigma_{all,}$ $B = \sqrt{P/\sigma all}$ Axial force, P (KN) = 8760.95

Foundation Width, B (m) = **4.57**

Provided Foundation Width, B (m) = **4.60**

5. Contact pressure

$\sigma_{max} = \frac{P}{A}\left(1+6\frac{e_x}{B}+6\frac{e_y}{B}\right) \leq \sigma_{ult}$ $\sigma_{min} = \frac{P}{A}\left(1-6\frac{e_x}{B}-6\frac{e_y}{B}\right)$ $e_x = \frac{M_x}{P}$ $e_y = \frac{M_y}{P}$

M_x (KNm) = 942.59 e_x (m) = 0.1076 σ_{max} (Kpa) = 533.88 Area, A(m^2) = 21.16

M_y (KNm) = 1001.71 e_y (m) = 0.1143 σ_{min} (Kpa) = 294.18 **Status - Ok! Area is adequate**

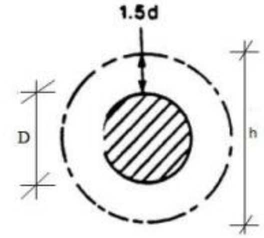
6. Foundation Thickness

Thickness, d (m) = **1.25** Column Diameter, D (m) = 0.85

6.1 Check trial foundation thickness for punching shear

The punching shear resistance, $V_{Rd1} = 0.25f_{ctd}.K1.K2.U.d$, $K_1 = 1+50\rho \leq 2$ $K_2 = 1.6\text{-}d \geq 1$

$U = \Pi.h = \Pi\,(1.5d+D+1.5d) = \Pi\,(3d+D)$ For circular column Developed shear, $V_1 = \sigma A$, $\sigma = \frac{\sigma 1 + \sigma 2}{2}$



$\sigma_1 = \sigma_{min} + \frac{(\frac{B-3d-D}{2})(\sigma_{max}-\sigma_{min})}{B}$ $\sigma_2 = \sigma_{min} + \frac{(\frac{B+3d+D}{2})(\sigma_{max}-\sigma_{min})}{B}$

Net developed shear, $V_{d1} = P\text{-}V_1$ $\rho_{min} = 0.5/f_{yk}$ $A = \frac{\Pi}{4}(3d+D)^2$

The thickness is sufficient for punching shear if $V_{Rd1} > V_{d1}$ $A\,(m^2) = 16.611$

$\rho_{min} =$ 0.0017 $K_2 = 1.00$ V_{Rd1} (KN) = **5046.63** V_{d1} (KN) = **1883.60**

U (m) = 14.45 $K_1 = 1.08$ V_1 (KN) = 6877.35

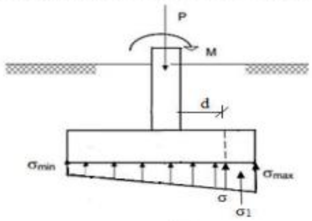
σ_1 (Kpa) = 294.18 σ_2 (Kpa) = 533.884 σ (Kpa) = 414.034

Status - Ok! Thickness is adequate for punching shear

6.2 Check trial foundation thickness for wide beam shear

The wide beam shear resistance, $V_{Rd2} = 0.25f_{ctd}k_1k_2bd$ Developed wide beam shear, $V_{d2} = \sigma_1 A$, $\sigma_1 = \frac{\sigma + \sigma max}{2}$

The thickness is sufficient for wide beam shear if $V_{Rd2} > V_{d2}$ $A = B\,\frac{B-D-2d}{2}$ $\sigma = \sigma_{min} + \frac{(\frac{B+2d+D}{2})(\sigma_{max}-\sigma_{min})}{B}$



V_{Rd2} (KN) = **1606.39** σ (Kpa) = 501.316 σ_1 (Kpa) = 517.6 $A\,(m^2) = 2.88$

V_{d2} (KN) = **1488.1**

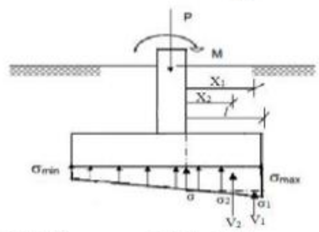
Status - Ok! Thickness is adequate for wide beam shear

6.3. Check trial foundation thickness for bending moment

Developed moment, $M_{sd} = \sum\sigma.A.x = V_1X_1 + V_2X_2$ $V_1 = \sigma_1 l$ $V_2 = \sigma_2 l$

$l = \frac{1}{2}(B-D)$ $X_2 = \frac{1}{2}l$ $X_1 = \frac{2}{3}l$ $\sigma = \sigma_{min} + \frac{(\frac{B+D}{2})(\sigma_{max}-\sigma_{min})}{B}$

The concrete moment capacity, $M = 0.32f_{cd}bd^2$ $\sigma_1 = \frac{\sigma_{max} - \sigma}{2}$



l = 1.875 $X_2 = 0.938$ $X_1 = 1.250$ $\sigma_2 = \sigma$

σ (Kpa) = 436.18 σ_1 (Kpa) = 48.852 σ_2 (Kpa) = 436.180

V_1 (KN/m) = 91.5979 V_2 (KN/m) = 817.837 M_{sd} (KN-m/m) = **881.220**

M (KN-m/m) = **5666.67**

Status - Ok! The thickness is adequate for bending moment

7. Reinforcement Calculation $A_s = \rho bd$ $\rho = \frac{fcd}{fyd}\left[1 - \sqrt{1 - \frac{2Msd}{fcdbd2}}\right]\rho_{min}$ Spacing, $S = \frac{bas}{As}$

$\rho =$ 0.0022 $A_s\,(mm^2) =$ **2773.22** **Ø = 24** S (mm) = **163.045**

Use	Ø	24	C/C	160	mm

8. Development length l_d (mm) = **1517.38** $l = \frac{B-D}{2}$ - Cover $l_{d,\,avl}$ (mm) = **1825**

$l_d = \frac{\phi fyd}{4fbd}$ $f_{bd} = f_{ctd}$ **Status - Bend the bars upward is not mandatory!**

Figure C.33 Sample foundation design for G+12 building with C-25 concrete

C.5.2 SAMPLE STRUCTURAL DESIGN FOR C-40 CONCRETE

C.5.2.1 SAMPLE STRUCTURAL DESIGN FOR G+2 BUILDING WITH C-40 CONCRETE

C.5.2.1.1 SAMPLE SLAB DESIGN FOR G+2 BUILDING WITH C-40 CONCRETE

Following similar procedure as sample slab design with C-25 concrete, design of slab with C-40 concrete is done as shown below.

Table C.49 Sample slab design for G+2 building using C-40 concrete

DESIGN OF TWO WAY SOLID SLAB BASED ON ES EN:2015

SAMPLE SLAB DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building — **Date:** 20-May-18

Description: Analysis & Design of slab for G+2 building — **Design by:** Yohannes Sefiw

1 Material Constant

Concrete Grade (f_{cu})	40	Design Material Strength (mpa)	
R.Steel Grade (f_{yk})	300	f_{cd}	18.13
Cover [mm]	15	f_{yd}	260.87

β_a for 2:1	β_a for 1:1	L_y/L_x	β_a
35.00	45.00	1.09	44.09

2 Depth Determination

Panel Name	FS-9		d_{eff} required [mm]	D required [mm]	D provided [mm]
Depth	L_x [m]	L_y [m]			
	5.50	6.00	106.03	130.00	150

3 Total Load calculation

Description	Thickness t	Unit weight	Load
Slab	0.15	25	3.75
Floor finish	0.02	27	0.54
Ceiling Plaster	0.02	23	0.46
Cement Screed	0.03	23	0.69
Partition Wall	0.10	14	0.80
Total Dead Load gk (KN/m^2)			6.24
Live Load qk (KN/m^2			3
Design load P_d (KN/m^2)			12.92

Partial safety factor	
γ_{DL}	1.35
γ_{LL}	1.50

Wall Description	
Height (m)	3.05
Length (m)	5.50

4 Total Moment calculation

ρ values	ρ_1	ρ_2	ρ_3	ρ_4	n_d
	1.333	1.333	1.333	1.333	0.000
Moment Coefficent	α_{xs}	α_{ys}	α_{xs}	α_{ys}	β
	0.037	0.032	0.028	0.024	0.26
Moment (KN-m/m)	M_{xs}	M_{ys}	M_{xf}	M_{yf}	
	14.46	12.51	10.94	9.38	

5 Reinforcement Calculation

k-value	850	730	640	550
ρ	0.33	0.29	0.25	0.21
A_{min}[mm^2]	218	218	218	218
As_{req} [mm^2]	433	374	326	279
As_{prv} [mm^2]	433	374	326	279
Ø (mm)	8	8	8	8
No of Bars/panel	56	43	41	32
S_{max} [mm]	300	300	300	300
S_{Cal}[mm]	110.00	130.00	150.00	180.00
S_{prv} [mm]	110.00	130.00	150.00	180.00

Wall on beam TS

Length of wall (m)	5.50
Length of beam (m)	5.50
Wall Thickness (m)	0.004
Hieght of wall (m)	2.85
γ(KN/m^3)	27.00
Gk (KN/m)	0.31

6 Total Un-factor Load transfer to beams

	Load Transfer on Beams			L_y/L_x = 1.09
Shear coeffcient	V_{bxc}	V_{bxd}	V_{byc}	V_{byd}
	0.361	0.000	0.330	0.000
Load on Beams	R_{cx}	R_{dx}	R_{cy}	R_{dy}
Total design load	18.33	N.A.	16.76	N.A.
Live Load	5.95	N.A.	5.45	N.A.
Dead Load	12.37	N.A.	11.32	N.A.

Wall on beam BS

Length of wall (m)	5.50
Length of beam (m)	5.50
Wall Thickness (m)	0.004
Hieght of wall (m)	2.85
γ(KN/m^3)	27.00
Gk (KN/m)	0.31

Note:-	N.A.-Means Not Applicable		1 -Continuous
	input data		0 -Discontinous

Wall on beam LS		**Wall on beam RS**	
Length of wall (m)	6.00	Length of wall (m)	6.00
Length of beam (m)	6.00	Length of beam (m)	6.00
Wall Thickness (m)	0.10	Wall Thickness (m)	0.10
Hieght of wall (m)	2.85	Hieght of wall (m)	2.85
γ(KN/m^3)	14.00	γ(KN/m^3)	14.00
Gk (KN/m)	3.99	Gk (KN/m)	3.99

C.5.2.1.2 SAMPLE STAIRCASE DESIGN FOR G+2 BUILDING WITH C-40 CONCRETE

Following similar procedure as sample staircase design with C-25 concrete, design of staircase with C-40 concrete is done as shown below.

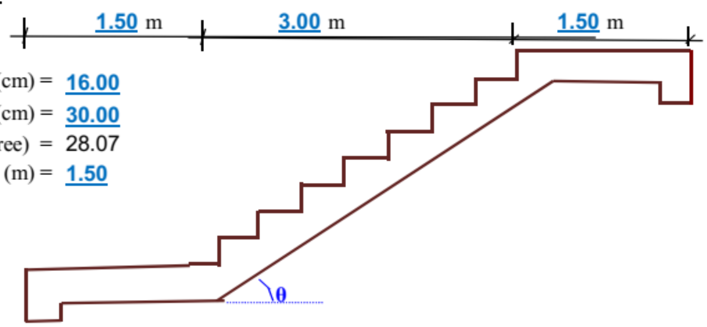
DESIGN OF STAIRCASE BASED ON ES EN:2015

SAMPLE STAIRCASE DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building — **Date:** 21-May-18

Description: Analysis and Design of Staircase — **Design by:** Yohannes Sefiw

1. Stair No. 1



Riser (cm) = 16.00
Thread (cm) = 30.00
θ (Degree) = 28.07
Stair width (m) = 1.50

2. Materials constant:

Concrete: C - 40
Steel: S - 300

f_{cu} (mpa) = 32 — f_{cd} (mpa) = 18.13
f_{yk} (mpa) = 300 — f_{yd} (mpa) = 260.87
Cover, C (mm) = 15

3. Depth:

$$d = \left(0.4 + 0.6\frac{f_{yk}}{400}\right)\frac{L_x}{\beta_a}$$

β_a = 28

Required, d (mm) = 182.14
Required, D (mm) = 204.14
Provided, D (mm) = 210
Provided, d (mm) = **188.00**

4. Loading:

I. Load on flight:

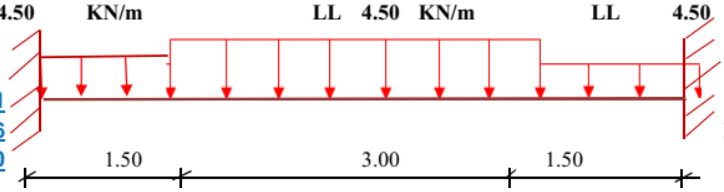
Own wt. of slab (Waist) (KN/m) = 8.93
Due to steps per unit run (KN/m) = 3.00
3cm cement screed (KN/m) = 0.69
3cm Marble floor finish (KN/m) = 0.81
On thread (KN/m) = 2.25
On riser (KN/m) = 3.37
1.5cm plastering (KN/m) = 0.59
Total Dead Load on flight (KN/m) = **18.13**
Live Load (KN/m^2) = 3
Live load per unit meter KN/m) = **4.50**
Design Load = 1.35DL + 1.5LL
P_d (KN/m) = **31.23**

II. Load on Landing:

Own wt. of slab (KN/m) = 7.88 KN/m
3cm cement screed (KN/m) = 1.04 KN/m
3cm terrazzo floor finish (KN/m) = 1.22 KN/m
1.5cm plastering (KN/m) = 0.52 KN/m
Total Dead Load on landing (KN/m) = **10.64 KN/m**
Live Load (KN/m^2) = 3
Live load per unit meter KN/m) = **4.50 KN/m**
Design Load = 1.35DL + 1.5LL
P_d (KN/m) = **21.12 KN/m**

5. Modeling

DL	10.64	KN/m	DL	18.13	KN/m	DL	10.64	KN/m
LL	4.50	KN/m	LL	4.50	KN/m	LL	4.50	KN/m



	Left	Right
R	R_1 78.51	R_2 78.51
DL	43.16	43.16
LL	13.50	13.50

6. Load transfer on Beam

Length (m) = 6.00

R_1	DL (KN/m) =	7.19
	LL (KN/m) =	2.25
R_2	DL (KN/m) =	7.19
	LL (KN/m) =	2.25

7. Design actions:

Negative Moment (KN-m) = **84.20**

Posetive Moment (KN-m) = **44.94**

Shear Force (KN) = 78.51

Final deflection shall not exceed the value:

$\delta = \frac{L_e}{200}$ = **30.00** mm **OK Deffle****ction is within the limit!**

8. Check for Deflection

$\Delta_{max} = \frac{wL^4}{384EI}$

W (KN/m) = 18.89

L (m) = 6.00

E (Gpa) = 32.5

I (m^4) = 0.0011576

Δ (mm) = **1.7**

9. Check for Shear Capacity

$\rho_{min} = \frac{0.5}{f_{yk}}$ ρ_{min} = 0.00167 K_1 = 1.08 K_2 = 1.41

$V_c = 0.25 f_{ctd} k_1 k_2 b_w d$ f_{ctd} = 1.03 **Shear Capacity, V_c (KN) =** 111.08 **OK Stair has enough shear resistance!**

10. Reinforcement calculation

m = 17.98 C_1 = 0.14

10.1 Main Reinforcement

$A_s = \rho bd$ $\rho = ½(C_1 - (\sqrt{C_1^2 - \frac{4M}{bd^2 C_2}}))$ C_2 = 1,876.5 ρ = 0.00638

10.1.1 Negative Reinforcement

Ø = **14** $A_{s,Prv}$ = Max [ρbd, ρ_{min}bd]

$A_{s,Prv}$ (mm^2) = 1799.44

Use Ø	14	C/C	120	mm

10.1.2 Posetive Reinforcement

Ø = **10** ρ = 0.00333

$A_{s,Prv}$ (mm^2) = 938.81

Use Ø	10	C/C	120	mm

10.2 Secondary Reinforcement

$A_{s,Prv}$ = Max [0.2As, ρ_{min}bd]

$A_{s,Prv}$ (mm^2) = 470.00 Ø = **8**

Use Ø	8	C/C	160	mm

Figure C.34 Sample staircase design for G+2 building using C-40 concrete

C.5.2.1.3 SAMPLE BEAM DESIGN FOR G+2 BUILDING WITH C-40 CONCRETE

Following similar procedure as sample beam design with C-25 concrete, design of beam with C-40 concrete is done as shown below.

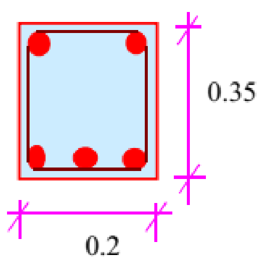
DESIGN OF BEAM BASED ON ES EN:2015

SAMPLE BEAM DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building Date: 22-May-18

Description: Analysis and Design of Floor Beam Design by: Yohannes Sefiw

1. First floor beam (on axis B span 4-3)



Depth **0.35** m

Width **0.20** m

$Ø_m$ 0.024 m

Cover **0.025** m

2. Effective depth calculation

d_{eff} = D - Cover - $Ø_m$/2 - $Ø_s$

d_{eff} = 0.305 m

3. Depth for defflection

$L_{e\,(m)}$ = **6.00** $d \geq (0.4 + \frac{f_{yk}}{400})\frac{L_e}{\beta_a}$

β_a = **28.00**

d (m) = 0.246 **OK!**

4. Design bending moment and shear force

Design Negative Moment Mu = **119.90** kN-m

Design Positive Moment Mu = **52.12** kN-m

Design Shear Force, Vsd = **95.74** KN

5. Material constant

Concrete Grade C- 40

$f_{ck} =$ 32,000 kpa

$f_{ctk} =$ 2,117 kpa

$\gamma c =$ 1.5

$f_{cd} =$ 18,133 kpa

$f_{ctd} =$ 1,411 kpa

$E_{cm} =$ 32,490 kpa

$f_{ck} = 0.8 f_{cu}$

$f_{ctk} = 0.21 f_{ck}^{2/3}$

$f_{cd} = 0.85 f_{ck}/\gamma_c$

$f_{ctd} = f_{ctk}/\gamma_c$

$E_{cm} = 9.5(f_{ck}+8)^{1/3}$

$f_{yd} = f_{yk}/\gamma_s$

$\rho_{min} = \frac{0.6}{f_k}$

Steel Grade S- 300

fyk = 300,000.0 kpa

$\gamma s =$ 1.15

fyd = 260869.57 kpa

Es = 200000.00 kpa

$\rho_{min} = 0.002$

$\rho_{max} = 0.04$

6. Design for flexure

$$\rho_{req} = \frac{1}{m}\left[1 - \sqrt{1 - \frac{2m_u}{f_{cd} b d^2}}\right] \qquad m = \frac{f_{yd}}{f_{cd}} \qquad \mu = \frac{M_u}{f_{cd} b d^2}$$

$\rho = \text{Max}(\rho_{req}, \rho_{min})$

$As = \rho bd$

Negative Reinforcement		**Positive Reinforcement**	
$m =$	14.39	$m =$	14.39
$\mu =$	0.355	$\mu =$	0.154
Check Ducklity -	**OK!**	Check Ducklity -	**OK!**
Beam Type -	**Double Reinforced!**	Beam Type -	**Single Reinforced!**
$\rho_{req} =$	0.0321	$\rho_{req} =$	0.0117
$As_1 =$	0.00196 m^2	$As_1 =$	0.00072 m^2
$As_2 =$	0.00095 m^2	$As_2 =$	0.00000 m^2
$Ø_m =$	24	$Ø_m =$	16
$n_1 =$	4.33	$n_1 =$	3.56
$n_2 =$	2.11	$n_2 =$	0.00
Use	**5 Ø 24**	**Use**	**4 Ø 16**
$As_{prvd} =$	0.00226	$As_{prvd} =$	0.0008
Capacity =	131.97 KN-m	Capacity =	57.92
Reserve =	9.15%	Reserve =	10.02%

7. Design for Shear

$V_{Rd} = 0.25\, fcd\, b_w\, d > V_{sd}$

$V_c = 0.25\, f_{ctd}\, k_1 k_2 b_w d$

$K1 = 1+50\rho < 2$ $\quad k_1 =$ 2.854

$k_2 = 1.6 - d > 1$ $\quad k_2 =$ 1.295

$\rho = As/bd$

$V_c =$ 79.54 KN

$S_{max} = 0.5d < 300mm$ for $2/3V_{RD} > V_{sd}$

$S_{max} = 0.3d < 200mm$ for $2/3V_{RD} < V_{sd}$

$S_{prv} = \text{Min}(S_{cal}, S_{max})$

$V_{Rd} =$ 207.40 KN

$V_s =$ 16.20 KN

Check Shear Resistance - **OK!**

Shear Reinforcement

$$s = \frac{A_v d f_{yd}}{V_s}$$

$V_s = V_{sd} - V_c$

$A_v =$ 0.00010

$Ø_s =$ 8

$S_{max} =$ 152.5 mm

$S_{cal} =$ 493.6 mm

$S_{prv} =$ 150 mm

Use Ø 8 C/C 150 mm

Figure C.35 Sample beam design for G+2 building with C-40

C.5.2.1.4 SAMPLE COLUMN DESIGN FOR G+2 BUILDING WITH C-40 CONCRETE

Following similar procedure as sample column design with C-25 concrete, design of column with C-40 concrete is done as shown below.

Table C.50 Column grouping for G+2 building with C-40 concrete

Axis	P (KN)	Interval	Group	Axis	P (KN)	Interval	Group
A-2	1208.01	1201-1600	C-1	E-2	1259.12	1201-1600	C-1
A-3	1204.5	1201-1600	C-1	E-3	1400.46	1201-1600	C-1
B-1	1194.09	801-1200	C-2	E-4	1203.83	1201-1600	C-1
B-2	1202.6	1201-1600	C-1	F-1	1232.46	1201-1600	C-1
B-3	1226.53	1201-1600	C-1	F-2	1442.01	1201-1600	C-1
B-4	1181.91	801-1200	C-2	F-3	1350.67	1201-1600	C-1
C-1	1079.45	801-1200	C-2	F-4	1121.32	801-1200	C-2
C-2	1254.92	1201-1600	C-1	G-1	1084.36	801-1200	C-2
C-3	1220.06	1201-1600	C-1	G-2	1382.04	1201-1600	C-1
C-4	1041.55	801-1200	C-2	G-3	1358.75	1201-1600	C-1
D-1	1087.57	801-1200	C-2	G-4	1052.60	801-1200	C-2
D-2	1197.4	801-1200	C-2	H-1	911.83	801-1200	C-2
D-3	1310.5	1201-1600	C-1	H-2	1124.33	801-1200	C-2
D-4	1125.44	801-1200	C-2	H-3	1124.33	801-1200	C-2
E-1	1181.11	801-1200	C-2	H-4	901.71	801-1200	C-2

As clearly shown on table 5-50, the column grouped in to two groups based on their base axial force; C-1 for axial force ranges between 1201 to 1600 KN and C-2 for axial force ranges between 801 to 1200 KN. In the interval the maximum axial force is taken for foundation design as shown in the table below;

Table C.51 Maximum axial force in each column group for G+2 with C-40 concrete

Interval	P_{max} (KN)	Group	No Member	Location
0-400	-	C-4	-	-
401-800	-	C-3	-	-
801-1200	1197.40	C-2	15	D-1
1201-1600	1442.01	C-1	15	F-2

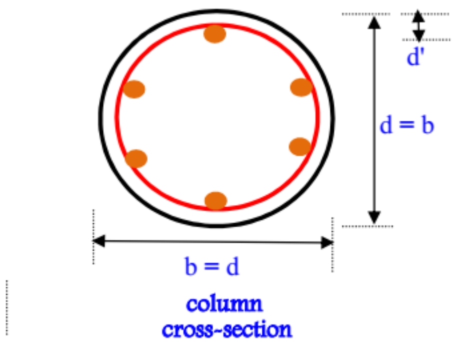
DESIGN OF CIRCULAR COLUMN BASED ON ES EN:2015

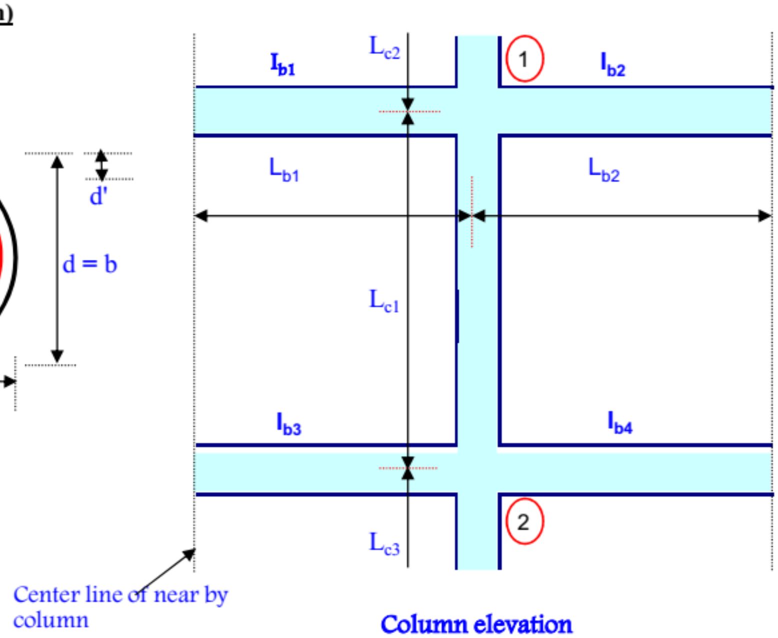
SAMPLE COLUMN DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building **Date:** 26-May-18

Description: Design of Column for G+2 Building (C-40) **Design by:** Yohannes Sefiw

1. C-2 (Ground floor Column)





2. Material constant

Concrete - Grade C- 40 Steel - Grade S- 300

f_{ck}	32000	kpa	$f_{ck} = 0.8 f_{cu}$	F_{yk}	300000	kpa
f_{ctk}	2116.6674	kpa	$f_{ctk} = 0.21 f_{ck}^{2/3}$	γs	1.15	
γc	1.5			F_{yd}	260,870	kpa
f_{cd}	18133.333	kpa	$f_{cd} = 0.85 f_{ck}/\gamma_c$	E_s	200,000	kpa
f_{ctd}	1411.1116	kpa	$f_{ctd} = f_{ctk}/\gamma_c$	$A_{s\ (min)}$	0.0004	m^2
E_{cm}	32489.543	kpa	$E_{cm} = 9.5(f_{ck}+8)^{1/3}$	$A_{s\ (max)}$	0.003925	m^2

3. Analysis Result:

Axial (kN)	Mom. x-x	Mom y-y
835.08	-74.28	-3.73
891.95	112.80	9.81

4. Structure Classification:

Second-order global elastic analysis was done. Therefore both sway and non-sway are taken care of.

5. Dimensions in x-x direction:

Item	Depth	Width
B_1 =	0.35	0.20
B_2 =	0.35	0.20
B_3 =	0.35	0.20
B_4 =	0.35	0.20
C_1 =	0.25	0.25
C_2 =	0.25	0.25
C_3 =	0.25	0.25

6. Dimensions in y-y direction:

Item	Depth	Width
B_1 =	0.35	0.20
B_2 =	0.35	0.20
B_3 =	0.35	0.20
B_4 =	0.35	0.20
C_1 =	0.25	0.25
C_2 =	0.25	0.25
C_3 =	0.25	0.25

L_{b1} =	5.50
L_{b2} =	6.00
L_{c1} =	3.20
L_{c2} =	3.20
L_{c3} =	1.50

L_{b1} =	6.00
L_{b2} =	6.00
L_{c1} =	3.20
L_{c2} =	3.20
L_{c3} =	1.50

DESIGN OF CIRCULAR COLUMN BASED ON ES EN:2015

SAMPLE COLUMN DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building **Date:** 26-May-18

Description: Design of Column for G+2 Building (C-40) **Design by:** Yohannes Sefiw

7. Limits of Slenderness:

$$\lambda \le 50 - 25\left(\frac{M_1}{M_2}\right)$$

$\frac{M_1}{M_2}$ = -0.66 $\qquad$ $\frac{M_1}{M_2}$ = -0.38

$\lambda \le$ 66.46 $\qquad$ $\lambda \le$ 59.51

But, the slenderness ratio is:

$$\lambda = \frac{L_e}{i} \qquad i = \text{Radius of gyration} = \sqrt{\frac{I_g}{A_g}}$$

A_g = 0.049 m^2

I_g = 0.00019 m^4

i = 0.063

L_e = Effective buckling length

8. Effective Buckling Length:

$$L_e = \frac{\alpha_m + 0.4}{\alpha_m + 0.8} L \ge 0.7L$$

$$\alpha_m = \frac{\alpha_1 + \alpha_2}{2}$$

$$\alpha_1 = \frac{I_{c1}/L_{c1} + I_{c2}/L_{c2}}{I_{b1}/L_{b1} + I_{b2}/L_{b2}}$$

$$\alpha_2 = \frac{I_{c1}/L_{c1} + I_{c3}/L_{c3}}{I_{b3}/L_{b3} + I_{b4}/L_{b4}}$$

About x-x direction.				About y-y direction.			
I_{c1} =	0.00019	I_{c1} =	0.00019	I_{c1} =	0.00019	I_{c1} =	0.00019
I_{c2} =	0.00019	I_{c3} =	0.00019	I_{c2} =	0.00019	I_{c3} =	0.00019
I_{b1} =	0.00071	I_{b3} =	0.00071	I_{b1} =	0.00071	I_{b3} =	0.00071
I_{b2} =	0.00071	I_{b4} =	0.00071	I_{b2} =	0.00071	I_{b4} =	0.00071
α_1 =	0.481	α_2 =	0.754	α_1 =	0.503	α_2 =	0.788
	α_m =	0.617			α_m =	0.645	

- the effective buckling length:

L_e = **2.297** $\qquad$ L_e = **2.314**

- Slenderness ratio:

λ = **36.750** **Not Slender** **Ignore Secondary Effects** $\qquad$ λ = **37.030** **Not Slender** **Ignore Secondary Effect**

9. Design Actions:

Calculate Eccentricities in the x-x Direction

$$\text{Total} = e_{tot} = e_e + e_a + e_2$$

Calculate Eccentricities in the y-y Direction

$$\text{Total} = e_{tot} = e_e + e_a + e_2$$

$e_e = \max \text{ of } \begin{cases} 0.6e_{02} + 0.4e_{01} \\ 0.4e_{02} \end{cases}$

$e_{01} = -0.0889$

$e_{02} = 0.1265$

e_e = 0.0506 m

$e_a = \dfrac{L_e}{300} \geq 200mm$

e_a = 0.02 m

e_2 = 0.00 m

e_{tot} = 0.0706 m

N_{sd} = 891.95 kN

$M_{sd\ x\text{-}x}$ = 62.96 kN-m

$e_e = \max \text{ of } \begin{cases} 0.6e_{02} + 0.4e_{01} \\ 0.4e_{02} \end{cases}$

$e_{01} = -0.0045$

$e_{02} = 0.0110$

e_e = 0.0048

$e_a = \dfrac{L_e}{300} \geq 200mm$

e_a = 0.02 m

e_2 = 0.00 m

e_{tot} = 0.0248 m

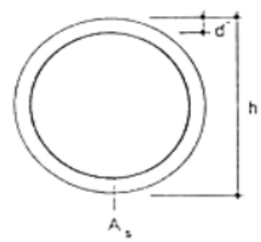
$M_{sd\ y\text{-}y}$ = 22.13 kN-m

10. Reinforcement Calculation:

10.1 Axial Reinforcement

d'/h = 0.1 e_{yd} = 0.002 Use - **Uiaxial Chart No. 12**

$$\upsilon_{sd} = \frac{N_{sd}}{f_{cd} A_c} \qquad \mu_{sd,x-x} = \frac{M_{sd,x-x}}{f_{cd} A_c h} \qquad \mu_{sd,y-y} = \frac{M_{sd,y-y}}{f_{cd} A_c b}$$



v_{sd} = 1.003 $\mu_{sd,x\text{-}x}$ = 0.283 $\mu_{sd,y\text{-}y}$ = 0.100

μ_{sd} = 0.283 μ_{sd} = Max ($\mu_{sd,x\text{-}x}$, $\mu_{sd,y\text{-}y}$)

ώ = **1.10**

$$A_{s,tot} = \frac{\omega A_c f_{cd}}{f_{yd}}$$

$A_{s,\,min} < A_{s,\,prv} < A_{s,\,max}$

$A_{s,\,prv}$ = Max ($A_{s,\,min}$, $A_{s,\,tot}$)

$A_{s,\,tot}$ = 0.0037514 m^2 **$A_{s,\,prv}$ = 0.00375** m^2

$Ø_m$ = 20

No Bars= 11.95

Use	12	Ø	20

10.2 Check bar Congestion per layer

$$n_{max} = \frac{\Pi(D - 2C - 2Øs)}{Øm + S}$$

Cover, C (mm) = **25.00**

Max Aggregate Size, S (mm) = **2.00**

Max No Bars, n_{max} = **26** Status - **Ok! No bar congestion**

10.3 Shear Reinforcement

$V_{Rd} = 0.25f_{cd}bd > V_{sd}$ $V_c = 0.25f_{ctd}K_1K_2bd$ $K_1 = 1+50\rho < 2$ $k_2 = 1.6 - d > 1$

$\rho = As/bd$ $S_{cal} = A_vf_{yd}d/V_s$ $V_s = V_{sd} - V_c$ $A_v = 2a_s$

S_{max} = min [$12Ø_m$, b, 300mm]

V_{RD} (KN)	Status	V_{sdx} (KN)	V_{sdy} (KN)
283.33	Ok!	75.39	112.45
K_1	K_2	V_c (KN)	
2.00	1.35	59.53	
Φ (mm)	S_{max} (mm)	S_{cal} (mm)	S_{prv} (mm)
10	240	193	190

Use	Ø	10	C/C	190	mm

Figure C.36 Sample column design for G+2 building C-40 concrete

C.5.2.1.5 SAMPLE FOUNDATION DESIGN FOR G+2 BUILDING WITH C-40 CONCRETE

Following similar procedure as sample foundation design with C-25 concrete, design of foundation with C-40 concrete is done as shown below.

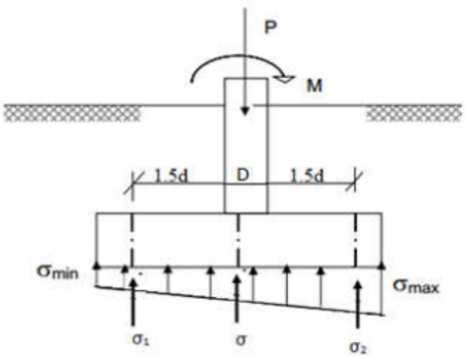
DESIGN OF SQUARE ISOLATED FOUNDATION BASED ON ES EN:2015

SAMPLE FOUNDATION DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building   Date: 26-May-18

Description: Design of Square Isolated Foundation for G+2 Building (C-40)   Design by: Yohannes Sefiw

1. Foundation 1 (F-1)



2. Material Constant

Concrete Grade C- 40

f_{ck} = 32,000.000000 kpa

f_{ctk} = 2,116.667364 kpa

γc = 1.50

f_{cd} = 18,133.333333 kpa

f_{ctd} = 1,411.111576 kpa

E_{cm} = 32,489.542987 kpa

Steel Grade S- 300

f_{yk} = 300,000.0000 Kpa

γs = 1.15

f_{yd} = 260,869.5652 Kpa

E_s = 200,000.0000 Kpa

Cover, C (mm) = 50

3. Soil Property

Ground Type - Dense sand

Facter of Safety, Fs = 2.00

$\sigma_{ult} = F_s . \sigma_{al}$ Allowble soil bearing capacity, σ_{all} = 420 Kpa

Ultimate Soil bearing capacity, σ_{ult} = **840** kpa

4. Proportioning

$A = B^2 = P/\sigma_{all,}$ $B = \sqrt{P/\sigma all}$ Axial force, P (KN) = 1442.01   Foundation Width, B (m) = **1.85**

Provided Foundation Width, B (m) = **1.85**

5. Contact pressure

$\sigma_{max} = \frac{P}{A}\left(1 + 6\frac{e_x}{B} + 6\frac{e_y}{B}\right) \le \sigma_{ult}$ $\sigma_{min} = \frac{P}{A}\left(1 - 6\frac{e_x}{B} - 6\frac{e_y}{B}\right)$ $e_x = \frac{M_x}{P}$ $e_y = \frac{M_y}{P}$

M_x (KNm) = 114.39 e_x (m) = 0.0793 σ_{max} (Kpa) = 647.34   Area, A(m^2) = 3.4225

M_y (KNm) = 124.11 e_y (m) = 0.0861 σ_{min} (Kpa) = 195.32   **Status - Ok! Area is adequate**

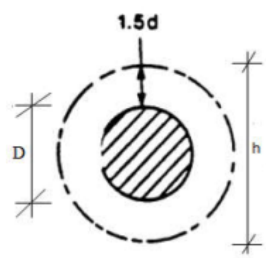
6. Foundation Thickness

Thickness, d (m) = **0.45**   Column Diameter, D (m) = 0.30

6.1 Check trial foundation thickness for punching shear

The punching shear resistance, $V_{Rd1} = 0.25 f_{ctd}.K1.K2.U.d$, $K_1 = 1+50\rho \le 2$ $K_2 = 1.6-d \ge 1$

$U = \Pi.h = \Pi\,(1.5d+D+1.5d) = \Pi\,(3d+D)$ For circular column   Developed shear, $V_1 = \sigma A$, $\sigma = \frac{\sigma 1+\sigma 2}{2}$



$\sigma_1 = \sigma_{min} + \frac{\left(\frac{B-3d-D}{2}\right)(\sigma_{max}-\sigma_{min})}{B}$ $\sigma_2 = \sigma_{min} + \frac{\left(\frac{B+3d+D}{2}\right)(\sigma_{max}-\sigma_{min})}{B}$

Net developed shear, $V_{d1} = P - V_1$ $\rho_{min} = 0.5/f_{yk}$ $A = \frac{\Pi}{4}(3d+D)^2$

The thickness is sufficient for punching shear if $V_{Rd1} > V_{d1}$ A (m^2) = 2.137

ρ_{min} = 0.0017 K_2 = 1.15 V_{Rd1} (KN) = **1025.20** V_{d1} (KN) = **541.55**

U (m) = 5.18 K_1 = 1.08 V_1 (KN) = 900.456

σ_1 (Kpa) = 219.76 σ_2 (Kpa) = 622.907   σ (Kpa) = 421.332

Status - Ok! Thickness is adequate for punching shear

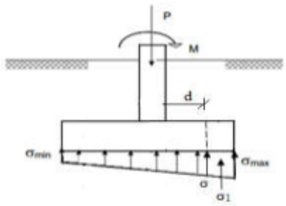
6.2 Check trial foundation thickness for wide beam shear

The wide beam shear resistance, $V_{Rd2} = 0.25 f_{ctd} k_1 k_2 bd$

The thickness is sufficient for wide beam shear if $V_{Rd2} > V_{d2}$

Developed wide beam shear, $V_{d2} = \sigma_1 A$, $\sigma_1 = \frac{\sigma + \sigma max}{2}$

$A = B\,\frac{B-D-2d}{2}$ $\sigma = \sigma_{min} + \frac{(\frac{B+2d+D}{2})(\sigma_{max}-\sigma_{min})}{B}$



V_{Rd2} (KN) = **365.89**

V_{d2} (KN) = **365.34**

σ (Kpa) = 567.932 σ_1 (Kpa) = 607.637 A (m^2) = 0.60

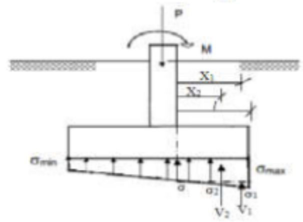
Status - Ok! Thickness is adequate for wide beam shear

6.3. Check trial foundation thickness for bending moment

Developed moment, $M_{sd} = \sum \sigma.A.x = V_1X_1 + V_2X_2$ $V_1 = \sigma_1 l$ $V_2 = \sigma_2 l$

$l = \frac{1}{2}(B-D)$ $X_2 = \frac{1}{2} l$ $X_1 = \frac{2}{3} l$ $\sigma = \sigma_{min} + \frac{(\frac{B+D}{2})(\sigma_{max}-\sigma_{min})}{B}$

The concrete moment capacity, $M = 0.32 f_{cd} bd^2$ $\sigma_1 = \frac{\sigma_{max} - \sigma}{2}$



l = 0.775 X_2 = 0.388 X_1 = 0.517 $\sigma_2 = \sigma$

σ (Kpa) = 457.98 σ_1 (Kpa) = 94.679 σ_2 (Kpa) = 457.982

V_1 (KN/m) = 73.376 V_2 (KN/m) = 354.936 M_{sd} (KN-m/m) = **175.449**

M (KN-m/m) = **1175.04**

Status - Ok! The thickness is adequate for bending moment

7. Reinforcement Calculation $A_s = \rho bd$ $\rho = \frac{fcd}{fyd}\left[1 - \sqrt{1 - \frac{2Msd}{fcdbd2}}\right] \rho_{min}$ Spacing, $S = \frac{bas}{As}$

ρ = 0.0034 A_s (mm^2) = **1532.1** **Ø = 16** S (mm) = **131.168**

Use	Ø	16	C/C	130	mm

8. Development length l_d (mm) = **739.47** $l = \frac{B-D}{2}$ - Cover $l_{d,\,avl}$ (mm) = **725**

$l_d = \frac{\phi fyd}{4fbd}$ $f_{bd} = f_{ctd}$ **Status - Bend the bars upward with a minimum length of 100mm!**

Figure C.37 Sample foundation design for G+2 building with C-40 concrete

C.5.2.2 SAMPLE STRUCTURAL DESIGN FOR G+7 BUILDING WITH C-40 CONCRETE

C.5.2.2.1 SAMPLE SLAB DESIGN FOR G+7 BUILDING WITH C-40 CONCRETE

The design value of slab for G+7 building is the same as design value of slab for G+2 building because of the architectural plan, slab layout, thickness of slab, slab loading and other necessary parameters are the same with G+2 building.

C.5.2.2.2 SAMPLE STAIRCASE DESIGN FOR G+7 BUILDING WITH C-40 CONCRETE

The design value of staircase for G+7 building is the same as design value of staircase for G+2 building because of the architectural plan, staircase layout, height of riser, width of tread, staircase loading and other necessary parameters are the same with G+2 building.

C.5.2.2.3 SAMPLE BEAM DESIGN FOR G+7 BUILDING WITH C-40 CONCRETE

Following similar procedure as sample beam design of for G+2 building, sample beam design for G+7 building is done as shown below.

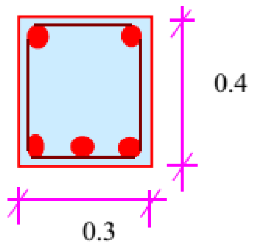
DESIGN OF BEAM BASED ON ES EN:2015

SAMPLE BEAM DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building Date: 26-May-18

Description: Design of Beam for G+7 building with C-40 concrete Design by: Yohannes Sefiw

1. Second floor beam (on axis D span 3-2)



Depth	0.40	m
Width	0.30	m
$Ø_m$	0.024	m
Cover	0.025	m

2. Effective depth calculation

$d_{eff} = D - Cover - Ø_m/2 - Ø_s$

$d_{eff} =$ 0.355 m

3. Depth for defflection

$L_{e\,(m)} =$ 6.00

$\beta_a =$ 28.00

$$d \geq (0.4 + \frac{f_{yk}}{400})\frac{L_e}{\beta_a}$$

d (m) = 0.246 **OK!**

4. Design bending moment and shear force

Design Negative Moment Mu = 151.95 kN-m

Design Positive Moment Mu = 61.47 kN-m

Design Shear Force, Vsd = 117.95 KN

5. Material constant

Concrete Grade C- 40

$f_{ck} =$ 32,000 kpa

$f_{ctk} =$ 2,117 kpa

$\gamma c =$ 1.5

$f_{cd} =$ 18,133 kpa

$f_{ctd} =$ 1,411 kpa

$E_{cm} =$ 32,490 kpa

$f_{ck} = 0.8 f_{cu}$

$f_{ctk} = 0.21 f_{ck}^{2/3}$

$f_{cd} = 0.85 f_{ck}/\gamma_c$

$f_{ctd} = f_{ctk}/\gamma_c$

$E_{cm} = 9.5(f_{ck}+8)^{1/3}$

$f_{yd} = f_{yk}/\gamma_s$

$\rho_{min} = \frac{0.6}{f_k}$

Steel Grade S- 300

fyk = 300,000.0 kpa

$\gamma s =$ 1.15

fyd = 260869.57 kpa

Es = 200000.00 kpa

$\rho_{min} =$ 0.002

$\rho_{max} =$ 0.04

6. Design for flexure

$$\rho_{req} = \frac{1}{m}\left[1 - \sqrt{1 - \frac{2m_u}{f_{cd}bd^2}}\right] \qquad m = \frac{f_{yd}}{f_{cd}} \qquad \mu = \frac{M_u}{f_{cd}bd^2}$$

$\rho = Max(\rho_{req}, \rho_{min})$

$As = \rho bd$

Negative Reinforcement		Positive Reinforcement	
$m =$	14.39	$m =$	14.39
$\mu =$	0.222	$\mu =$	0.090
Check Ducklity -	**OK!**	Check Ducklity -	**OK!**
Beam Type -	**Double Reinforced!**	Beam Type -	**Single Reinforced!**
$\rho_{req} =$	0.0176	$\rho_{req} =$	0.0065
$As_1 =$	0.00188 m^2	$As_1 =$	0.00070 m^2
$As_2 =$	0.00012 m^2	$As_2 =$	0.00000 m^2
$Ø_m =$	24	$Ø_m =$	16
$n_1 =$	4.15	$n_1 =$	3.46
$n_2 =$	0.27	$n_2 =$	0.00

Use **5 Ø 24**

As_{prvd} = 0.00226
Capacity = 177.47 KN-m
Reserve = 14.38%

Use **4 Ø 16**

As_{prvd} = 0.0008
Capacity = 70.43
Reserve = 12.73%

7. Check bar Congestion per layer

$n_{max} = \frac{b - 2Ø_s - 2C}{Ø_m + S} + 1$

Max Aggregate Size, S (mm) = 2.00
Max No Bars, n_{max} = 10
Status - **Ok! No bar congestion**

8. Design for Shear

$V_{Rd} = 0.25\, fcd\, b_w\, d > V_{sd}$

$V_c = 0.25\, f_{ctd}\, k_1 k_2 b_w d$

K1 = 1+50ρ < 2 k_1 = 2.062
k_2 = 1.6 – d > 1 k_2 = 1.245
ρ = As/bd
V_c = 96.45 KN

V_{Rd} = 402.33 KN
V_s = 21.50 KN
Check Shear Resistance - **OK!**

Shear Reinforcement

$s = \frac{A_v d f_{yd}}{V_s}$

$V_s = V_{sd} - V_c$
A_v = 0.00010
$Ø_s$ = 8

S_{max} = 177.5 mm
S_{cal} = 433 mm
S_{prv} = 170 mm

S_{max} = 0.5d < 300mm for $2/3V_{RD} > V_{sd}$
S_{max} = 0.3d < 200mm for $2/3V_{RD} < V_{sd}$
S_{prv} = Min (S_{cal}, S_{max})

Use **Ø 8 C/C 170 mm**

Figure C.38 Sample beam design for G+7 building with C-25

C.5.2.2.4 SAMPLE COLUMN DESIGN FOR G+7 BUILDING WITH C-40 CONCRETE

Following similar procedure as sample column design of G+2 building, sample column design for G+7 building is done as shown below.

Table C.52 Column grouping for G+7 building with C-40 concrete

Axis	P (KN)	Interval	Group	Axis	P (KN)	Interval	Group
A-2	3680.89	3601-4000	C-3	E-2	3962.1	3601-4000	C-3
A-3	3649.66	3601-4000	C-3	E-3	4274.95	4001-4400	C-2
B-1	3582.31	3201-3600	C-4	E-4	3593.81	3201-3600	C-4
B-2	3730.54	3601-4000	C-3	F-1	3784.63	3601-4000	C-3
B-3	3820.71	3601-4000	C-3	F-2	4496.77	> 4400	C-1
B-4	3613.7	3601-4000	C-3	F-3	4167.08	4001-4400	C-2
C-1	3359.93	3201-3600	C-4	F-4	3436.46	3201-3600	C-4
C-2	3856.46	3601-4000	C-3	G-1	3291.07	3201-3600	C-4
C-3	3762.98	3601-4000	C-3	G-2	4242.81	4001-4400	C-2
C-4	3263.97	3201-3600	C-4	G-3	4203.44	4001-4400	C-2
D-1	3405.98	3201-3600	C-4	G-4	3213.08	3201-3600	C-4
D-2	3622.6	3601-4000	C-3	H-1	2775.78	<3200	C-5
D-3	4012.97	4001-4400	C-2	H-2	3451.74	3201-3600	C-4
D-4	3391.68	3201-3600	C-4	H-3	3407.08	3201-3600	C-4
E-1	3686.31	3601-4000	C-3	H-4	2726.25	<3200	C-5

As clearly shown on table 5-53, the column grouped in to five groups based on their base axial force; C-1 for axial force greater than 4400 KN, C-2 for axial force ranges between 4001 to 4400 KN, C-3 for axial force ranges between 3601 to 4000 KN, C-4 for axial force ranges between 3201 to 3600 KN and C-5 for axial force less than 3200 KN. In the interval the maximum axial force is taken for foundation design as shown in the table below.

Table C.53 Maximum axial force in each column group for G+7 with C-40 concrete

Interval	P_{max} (KN)	Location of P_{max}	Group	No Member
< 3200	2775.78	H-1	C-5	2
3201-3600	3593.81	E-4	C-4	11
3601-4000	3962.1	E-2	C-3	11
4001-4400	4274.95	E-3	C-2	5
> 4400	4496.77	F-2	C-1	1

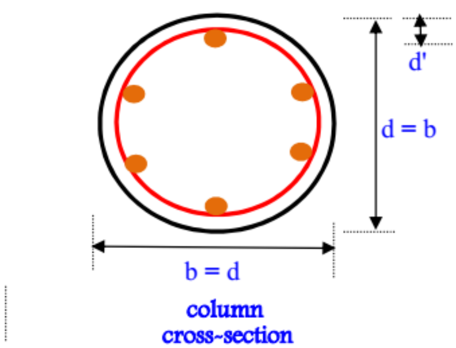
DESIGN OF CIRCULAR COLUMN BASED ON ES EN:2015

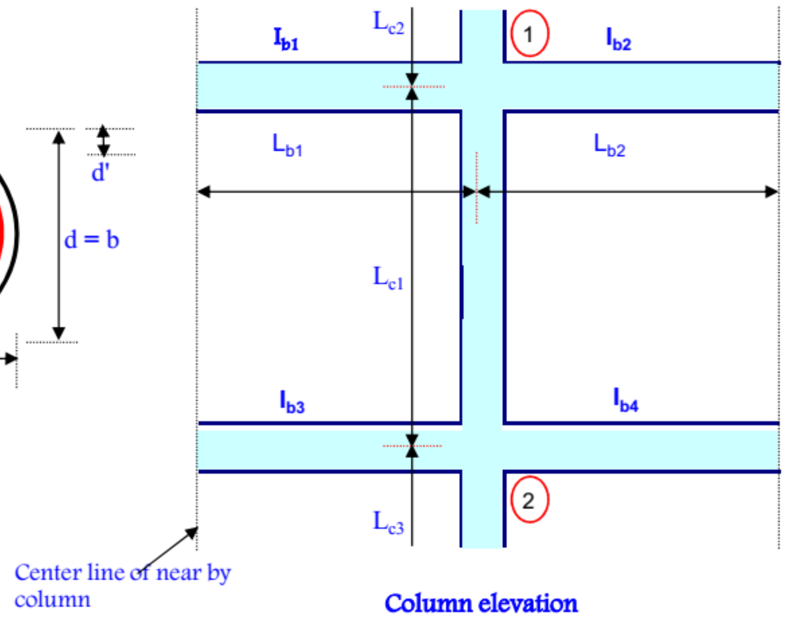
SAMPLE COLUMN DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building **Date:** 26-May-18

Description: Design of Column for G+7 Building (C-40) **Design by:** Yohannes Sefiw

1. C-1 (Foundation Column)





2. Material constant

Concrete - Grade C- 40 Steel - Grade S- 300

f_{ck}	32000	kpa	$f_{ck} = 0.8 f_{cu}$	F_{yk}	300000	kpa
f_{ctk}	2116.6674	kpa	$f_{ctk} = 0.21 f_{ck}^{2/3}$	γs	1.15	
γc	1.5			F_{yd}	260,870	kpa
f_{cd}	18133.333	kpa	$f_{cd} = 0.85 f_{ck}/\gamma_c$	E_s	200,000	kpa
f_{ctd}	1411.1116	kpa	$f_{ctd} = f_{ctk}/\gamma_c$	$A_{s\,(min)}$	0.0019	m^2
E_{cm}	32489.543	kpa	$E_{cm} = 9.5(f_{ck}+8)^{1/3}$	$A_{s\,(max)}$	0.018997	m^2

3. Analysis Result:

Axial (kN)	Mom. x-x	Mom y-y
4654.67	-109.82	-10.43
4693.44	397.70	10.92

4. Structure Classification:

Second-order global elastic analysis was done. Therefore both sway and non-sway are taken care of.

5. Dimensions in x-x direction:

Item	Depth	Width
B_1 =	0.40	0.30
B_2 =	0.40	0.30
B_3 =	0.40	0.30
B_4 =	0.40	0.30
C_1 =	0.55	0.55
C_2 =	0.55	0.55
C_3 =	0.55	0.55

L_{b1} =	5.50
L_{b2} =	6.00
L_{c1} =	3.20
L_{c2} =	3.20
L_{c3} =	1.50

6. Dimensions in y-y direction:

Item	Depth	Width
B_1 =	0.40	0.30
B_2 =	0.40	0.30
B_3 =	0.40	0.30
B_4 =	0.40	0.30
C_1 =	0.55	0.55
C_2 =	0.55	0.55
C_3 =	0.55	0.55

L_{b1} =	6.00
L_{b2} =	6.00
L_{c1} =	3.20
L_{c2} =	3.20
L_{c3} =	1.50

7. Limits of Slenderness:

$$\lambda \leq 50 - 25\left(\frac{M_1}{M_2}\right)$$

$\frac{M_1}{M_2}$ = -0.28 $\qquad$ $\frac{M_1}{M_2}$ = -0.96

$\lambda \leq$ 56.90 $\qquad$ $\lambda \leq$ 73.88

But, the slenderness ratio is:

$$\lambda = \frac{L_e}{i} \qquad i = \text{Radius of gyration} = \sqrt{\frac{I_g}{A_g}}$$

A_g = 0.237 m^2

I_g = 0.00449 m^4

i = 0.138

L_e = Effective buckling length

8. Effective Buckling Length:

$$L_e = \frac{\alpha_m + 0.4}{\alpha_m + 0.8} L \geq 0.7L$$

$$\alpha_m = \frac{\alpha_1 + \alpha_2}{2}$$

$$\alpha_1 = \frac{I_{c1}/L_{c1} + I_{c2}/L_{c2}}{I_{b1}/L_{b1} + I_{b2}/L_{b2}}$$

$$\alpha_2 = \frac{I_{c1}/L_{c1} + I_{c3}/L_{c3}}{I_{b3}/L_{b3} + I_{b4}/L_{b4}}$$

About x-x direction.				About y-y direction.			
I_{c1} =	0.00449	I_{c1} =	0.00449	I_{c1} =	0.00449	I_{c1} =	0.00449
I_{c2} =	0.00449	I_{c3} =	0.00449	I_{c2} =	0.00449	I_{c3} =	0.00449
I_{b1} =	0.00160	I_{b3} =	0.00160	I_{b1} =	0.00160	I_{b3} =	0.00160
I_{b2} =	0.00160	I_{b4} =	0.00160	I_{b2} =	0.00160	I_{b4} =	0.00160
α_1 =	**5.032**	α_2 =	**7.884**	α_1 =	**5.261**	α_2 =	**8.242**
	α_m =	**6.458**			α_m =	**6.752**	

- the effective buckling length:

L_e = **3.024** $\qquad$ L_e = **3.031**

- Slenderness ratio:

ì = **21.990** **Not Slender** **Ignore Secondary Effects** ì = **22.040** **Not Slender** **Ignore Secondary Effect**

9. Design Actions:

Calculate Eccentricities in the x-x Direction

$$\text{Total} = e_{tot} = e_e + e_a + e_2$$

$$e_e = \text{max of} \begin{cases} 0.6e_{02} + 0.4e_{01} \\ 0.4e_{02} \end{cases}$$

e_{01} = -0.0247

e_{02} = 0.0855

$\mathbf{e_e}$ = **0.0414** m

$$\mathbf{e_a} = \frac{L_e}{300} \geq 200mm$$

$\mathbf{e_a}$ = **0.02** **m**

$\mathbf{e_2}$ = **0.00** **m**

$\mathbf{e_{tot}}$ = **0.0614** **m**

$\mathbf{N_{sd}}$ = **4496.77** **kN**

$\mathbf{M_{sd\ x\text{-}x}}$ = **276.24** **kN-m**

Calculate Eccentricities in the y-y Direction

$$\text{Total} = e_{tot} = e_e + e_a + e_2$$

$$e_e = \text{max of} \begin{cases} 0.6e_{02} + 0.4e_{01} \\ 0.4e_{02} \end{cases}$$

e_{01} = -0.0024

e_{02} = 0.0025

$\mathbf{e_e}$ = **0.0010**

$$\mathbf{e_a} = \frac{L_e}{300} \geq 200mm$$

$\mathbf{e_a}$ = **0.02** **m**

$\mathbf{e_2}$ = **0.00** **m**

$\mathbf{e_{tot}}$ = **0.0210** **m**

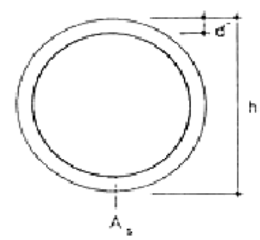
$\mathbf{M_{sd\ y\text{-}y}}$ = **94.40** **kN-m**

10. Reinforcement Calculation:

10.1 Axial Reinforcement

d'/h = 0.1 e_{yd} = 0.002 Use - **Uiaxial Chart No. 12**

$$\upsilon_{sd} = \frac{N_{sd}}{f_{cd} A_c} \qquad \mu_{sd,x-x} = \frac{M_{sd,x-x}}{f_{cd} A_c h} \qquad \mu_{sd,y-y} = \frac{M_{sd,y-y}}{f_{cd} A_c b}$$



$\mathbf{v_{sd}}$ = **1.044** $\mu_{sd,x\text{-}x}$ = 0.117 $\mu_{sd,y\text{-}y}$ = 0.040

μ_{sd} = **0.117** μ_{sd} = Max ($\mu_{sd,x\text{-}x}$, $\mu_{sd,y\text{-}y}$)

ώ = **0.40**

$$A_{s,tot} = \frac{\omega A_c f_{cd}}{f_{yd}}$$

$A_{s,\ min} < A_{s,\ prv} < A_{s,\ max}$

$A_{s,\ prv}$ = Max ($A_{s,\ min}$, $A_{s,\ tot}$)

$\mathbf{A_{s,\ tot}}$ = **0.0066025** $\mathbf{m^2}$ $\mathbf{A_{s,\ prv}}$ = **0.00660** m^2

$\mathbf{Ø_m}$ = **20**

No Bars= 21.03

Use 22 Ø 20

10.2 Check bar Congestion per layer

$$n_{max} = \frac{\Pi(D - 2C - 2Øs)}{Øm + S}$$

Cover, C (mm) = **25.00**

Max Aggregate Size, S (mm) = **2.00**

Max No Bars, n_{max} = **70** Status - **Ok! No bar congestion**

10.3 Shear Reinforcement

$V_{Rd} = 0.25f_{cd}bd > V_{sd}$ $V_c = 0.25f_{ctd}K_1K_2bd$ $K_1 = 1+50\rho < 2$ $k_2 = 1.6 – d > 1$

ρ = As/bd $S_{cal} = A_vf_{yd}d/V_s$ $V_s = V_{sd} - V_c$ $A_v = 2a_s$

S_{max} = min [12$Ø_m$, b, 300mm]

V_{RD} (KN)	**Status**	V_{sdx} (KN)	V_{sdy} (KN)
1371.33	**Ok!**	101.47	104.00
K_1	K_2	V_c (KN)	
2.00	1.05	224.10	
Φ (mm)	S_{max} (mm)	S_{cal} (mm)	S_{prv} (mm)
8	240	240	240

Use Ø 8 C/C 240 mm

Figure C.39 Sample column design for G+7 building C-40 concrete

C.5.1.2.5 SAMPLE FOUNDATION DESIGN FOR G+7 BUILDING WITH C-40 CONCRETE

Following similar procedure as sample foundation design of G+2 building, sample foundation design for G+7 building is done as shown below.

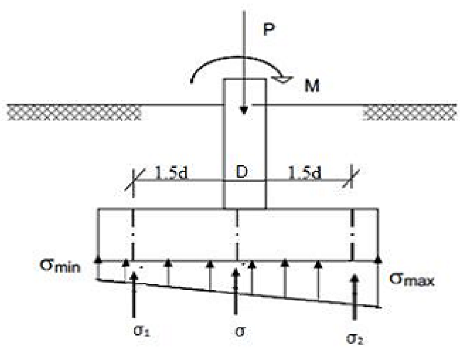
DESIGN OF SQUARE ISOLATED FOUNDATION BASED ON ES EN:2015

SAMPLE FOUNDATION DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building   Date: 27-May-18

Description: Design of Square Isolated Foundation for G+7 Building (C-40)   Design by: Yohannes Sefiw

1. Foundation 1 (F-1)



2. Material Constant

Concrete Grade C- 40

f_{ck} = 32,000.000000 kpa

f_{ctk} = 2,116.667364 kpa

γc = 1.50

f_{cd} = 18,133.333333 kpa

f_{ctd} = 1,411.111576 kpa

E_{cm} = 32,489.542987 kpa

Steel Grade S- 300

f_{yk} = 300,000.0000 Kpa

γs = 1.15

f_{yd} = 260,869.5652 Kpa

E_s = 200,000.0000 Kpa

Cover, C (mm) = 50

3. Soil Property

Ground Type - Dense sand

Facter of Safety, Fs = 2.00

$\sigma_{ult} = F_s \cdot \sigma_a$ Allowble soil bearing capacity, σ_{all} = 420 Kpa

Ultimate Soil bearing capacity, σ_{ult} = 840 kpa

4. Proportioning

$A = B^2 = P/\sigma_{all}$, $B = \sqrt{P/\sigma all}$ Axial force, P (KN) = 4496.77

Foundation Width, B (m) = 3.27

Provided Foundation Width, B (m) = 3.30

5. Contact pressure

$\sigma_{max} = \frac{P}{A}\left(1 + 6\frac{e_x}{B} + 6\frac{e_y}{B}\right) \leq \sigma_{ult}$ $\sigma_{min} = \frac{P}{A}\left(1 - 6\frac{e_x}{B} - 6\frac{e_y}{B}\right)$ $e_x = \frac{M_x}{P}$ $e_y = \frac{M_y}{P}$

M_x (KNm) = 384.51 e_x (m) = 0.0855 σ_{max} (Kpa) = 542.26   Area, A(m^2) = 10.89

M_y (KNm) = 390.14 e_y (m) = 0.0868 σ_{min} (Kpa) = 283.59   **Status - Ok! Area is adequate**

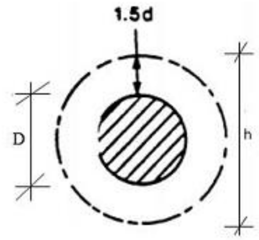
6. Foundation Thickness

Thickness, d (m) = 0.80   Column Diameter, D (m) = 0.55

6.1 Check trial foundation thickness for punching shear

The punching shear resistance, $V_{Rd1} = 0.25f_{ctd}.K1.K2.U.d$, $K_1 = 1+50\rho \le 2$ $K_2 = 1.6-d \ge 1$

$U = \Pi.h = \Pi\,(1.5d+D+1.5d) = \Pi\,(3d+D)$ For circular column Developed shear, $V_1 = \sigma A$, $\sigma = \frac{\sigma 1+\sigma 2}{2}$



$\sigma_1 = \sigma_{min} + \frac{(\frac{B-3d-D}{2})(\sigma_{max}-\sigma_{min})}{B}$ $\sigma_2 = \sigma_{min} + \frac{(\frac{B+3d+D}{2})(\sigma_{max}-\sigma_{min})}{B}$

Net developed shear, $V_{d1} = P-V_1$ $\rho_{min} = 0.5/f_{yk}$ $A = \frac{\Pi}{4}(3d+D)^2$

The thickness is sufficient for punching shear if $V_{Rd1} > V_{d1}$ $A\ (m^2) = 6.831$

$\rho_{min} =$ 0.0017 $K_2 =$ 1.00 V_{Rd1} (KN) = **2833.51** V_{d1} (KN) = **1675.88**

U (m) = 9.27 $K_1 =$ 1.08 V_1 (KN) = 2820.9

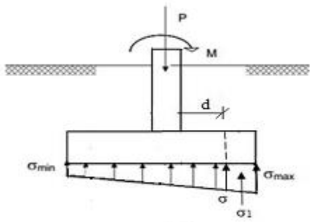
σ_1 (Kpa) = 297.31 σ_2 (Kpa) = 528.544 σ (Kpa) = 412.927

Status - Ok! Thickness is adequate for punching shear

6.2 Check trial foundation thickness for wide beam shear

The wide beam shear resistance, $V_{Rd2} = 0.25f_{ctd}k_1k_2bd$ Developed wide beam shear, $V_{d2} = \sigma_1 A$, $\sigma_1 = \frac{\sigma+\sigma max}{2}$

The thickness is sufficient for wide beam shear if $V_{Rd2} > V_{d2}$ $A = B\frac{B-D-2d}{2}$ $\sigma = \sigma_{min} + \frac{(\frac{B+2d+D}{2})(\sigma_{max}-\sigma_{min})}{B}$



V_{Rd2} (KN) = **1008.94** σ (Kpa) = 497.19 σ_1 (Kpa) = 519.73 $A\ (m^2) = 1.90$

V_{d2} (KN) = **986.18**

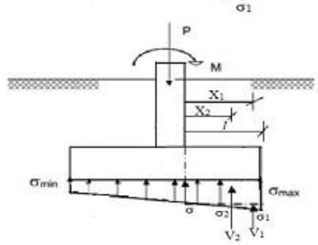
Status - Ok! Thickness is adequate for wide beam shear

6.3. Check trial foundation thickness for bending moment

Developed moment, $M_{sd} = \sum\sigma.A.x = V_1X_1 + V_2X_2$ $V_1 = \sigma_1 l$ $V_2 = \sigma_2 l$

$l = \frac{1}{2}(B-D)$ $X_2 = \frac{1}{2}l$ $X_1 = \frac{2}{3}l$ $\sigma = \sigma_{min} + \frac{(\frac{B+D}{2})(\sigma_{max}-\sigma_{min})}{B}$

The concrete moment capacity, $M = 0.32f_{cd}bd^2$ $\sigma_1 = \frac{\sigma_{max}-\sigma}{2}$



l = 1.375 X_2 = 0.688 X_1 = 0.917 $\sigma_2 = \sigma$

σ (Kpa) = 434.48 σ_1 (Kpa) = 53.889 σ_2 (Kpa) = 434.482

V_1 (KN/m) = 74.098 V_2 (KN/m) = 597.413 M_{sd} (KN-m/m) = **478.645**

M (KN-m/m) = **3713.71**

Status - Ok! The thickness is adequate for bending moment

7. Reinforcement Calculation $A_s = \rho bd$ $\rho = \frac{fcd}{fyd}\left[1-\sqrt{1-\frac{2Msd}{fcdbd^2}}\right]\rho_{min}$ Spacing, $S = \frac{bas}{As}$

$\rho =$ 0.0029 $A_s\ (mm^2)$ = **2342.9** **Ø = 20** S (mm) = **134.024**

Use | **Ø** | **20** | **C/C** | **130** | **mm**

8. Development length l_d (mm) = **924.34** $l = \frac{B-D}{2}$ - Cover $l_{d,\,avl}$ (mm) = **1325**

$l_d = \frac{\phi fyd}{4fbd}$ $f_{bd} = f_{ctd}$ **Status - Bend the bars upward is not mandatory!**

Figure C.40 Sample foundation design for G+7 building with C-40 concrete

C.5.2.3 SAMPLE STRUCTURAL DESIGN FOR G+12 BUILDING WITH C-40 CONCRETE

5.5.2.3.1 SAMPLE SLAB DESIGN FOR G+12 BUILDING WITH C-40 CONCRETE

The design value of slab for G+12 building is the same as design value of slab for G+2 building because of the architectural plan, slab layout, thickness of slab, slab loading and other necessary parameters are the same with G+2 building.

C.5.2.3.2 SAMPLE STAIRCASE DESIGN FOR G+12BUILDING WITH C-40 CONCRETE

The design value of staircase for G+12 building is the same as design value of staircase for G+2 building because of the architectural plan, staircase layout, height of riser, width of tread, staircase loading and other necessary parameters are the same with G+2 building.

C.5.2.3.3 SAMPLE BEAM DESIGN FOR G+12 BUILDING WITH C-40 CONCRETE

Following similar procedure as sample beam design of for G+2 building, sample beam design for G+12 building is done as shown below.

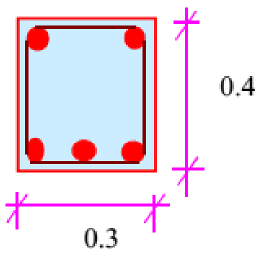
DESIGN OF BEAM BASED ON ES EN:2015

SAMPLE BEAM DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building   Date: 27-May-18

Description: Design of Beam for G+12 building with C-40 concrete   Design by: Yohannes Sefiw

1. First floor beam (on axis B span 4-3)



Depth	0.40	m
Width	0.30	m
$Ø_m$	0.02	m
Cover	0.025	m

2. Effective depth calculation

$d_{eff} = D - Cover - Ø_m/2 - Ø_s$

$d_{eff} =$ 0.359 m

3. Depth for deflection

$L_{e\,(m)} =$ 6.00

$\beta_a =$ 28.00

$$d \geq (0.4 + \frac{f_{yk}}{400})\frac{L_e}{\beta_a}$$

d (m) = 0.246 **OK!**

4. Design bending moment and shear force

Design Negative Moment Mu = 161.77 kN-m

Design Positive Moment Mu = 84.30 kN-m

Design Shear Force, Vsd = 139.84 KN

5. Material constant

Concrete Grade C- 40

$f_{ck} =$ 32,000 kpa

$f_{ctk} =$ 2,117 kpa

$\gamma c =$ 1.5

$f_{cd} =$ 18,133 kpa

$f_{ctd} =$ 1,411 kpa

$E_{cm} =$ 32,490 kpa

$f_{ck} = 0.8 f_{cu}$

$f_{ctk} = 0.21 f_{ck}^{2/3}$

$f_{cd} = 0.85 f_{ck}/\gamma_c$

$f_{ctd} = f_{ctk}/\gamma_c$

$E_{cm} = 9.5(f_{ck}+8)^{1/3}$

$f_{yd} = f_{yk}/\gamma_s$

$\rho_{min} = \frac{0.6}{f_k}$

Steel Grade S- 300

fyk = 300,000.0 kpa

γs = 1.15

fyd = 260869.57 kpa

Es = 200000.00 kpa

$\rho_{min} = 0.002$

$\rho_{max} = 0.04$

6. Design for flexure

$$\rho_{req} = \frac{1}{m}\left[1 - \sqrt{1 - \frac{2m_u}{f_{cd} b d^2}}\right] \qquad m = \frac{f_{yd}}{f_{cd}} \qquad \mu = \frac{M_u}{f_{cd} b d^2}$$

$\rho = Max(\rho_{req}, \rho_{min})$

$As = \rho b d$

Negative Reinforcement		**Positive Reinforcement**	
$m =$	14.39	$m =$	14.39
$\mu =$	0.231	$\mu =$	0.120
Check Ducklity -	**OK!**	Check Ducklity -	**OK!**
Beam Type -	**Double Reinforced!**	Beam Type -	**Single Reinforced!**
$\rho_{req} =$	0.0185	$\rho_{req} =$	0.0089
$As_1 =$	0.00199 m^2	$As_1 =$	0.00096 m^2

$As_2 = 0.00022 \; m^2$ | $As_2 = 0.00000 \; m^2$

$Ø_m =$ 20 | $Ø_m =$ 16

$n_1 = 6.34$ | $n_1 = 4.78$

$n_2 = 0.69$ | $n_2 = 0.00$

Use 7 Ø 20 | **Use 5 Ø 16**

$As_{prvd} = 0.0022$ | $As_{prvd} = 0.0010$

Capacity = 175.70 KN-m | Capacity = 87.83

Reserve = 7.93% | Reserve = 4.02%

7. Check bar Congestion per layer

$$n_{max} = \frac{b - 2Ø_s - 2C}{Ø_m + S} + 1$$

Max Aggregate Size, S (mm) = 2.00

Max No Bars, n_{max} = 11

Status - **Ok! No bar congestion**

8. Design for Shear

$V_{Rd} = 0.25\, fcd\, b_w\, d > V_{sd}$ | $V_{Rd} = 406.87$ KN

$V_c = 0.25\, f_{ctd}\, k_1 k_2 b_w d$ | $V_s = 44.55$ KN

Status - **OK! The section is adequate for shear**

$K1 = 1+50\rho < 2$ | $k_1 = 2.021$

$k_2 = 1.6 - d > 1$ | $k_2 = 1.241$

$\rho = As/bd$

$V_c = 95.29$ KN

$S_{max} = 0.5d < 300mm$ for $2/3V_{RD} > V_{sd}$

$S_{max} = 0.3d < 200mm$ for $2/3V_{RD} < V_{sd}$

$S_{prv} = Min\,(S_{cal}, S_{max})$

Shear Reinforcement

$$s = \frac{A_v d f_{yd}}{V_s}$$

$V_s = V_{sd} - V_c$

$A_v = 0.00006$ | $S_{max} = 179.5$ mm

$Ø_s =$ 6 | $S_{cal} = 118.9$ mm

$S_{prv} = 110$ mm

Use Ø 6 C/C 110 mm

Figure C.41 Sample beam design for G+12 building with C-40

C.5.2.3.4 SAMPLE COLUMN DESIGN FOR G+12 BUILDING WITH C-25 CONCRETE

Following similar procedure as sample column design of G+2 building, sample column design for G+12 building is done as shown below.

Table C.54 Column grouping for G+12 building with C-40 concrete

Axis	P (KN)	Interval	Group	Axis	P (KN)	Interval	Group
A-2	6434.81	6001-6600	C-3	E-2	6956.2	6601-7200	C-2
A-3	6452.57	6001-6600	C-3	E-3	7400.72	> 7200	C-1
B-1	6282.35	6001-6600	C-3	E-4	6403.73	6001-6600	C-3
B-2	6555.88	6001-6600	C-3	F-1	6641.12	6601-7200	C-2
B-3	6647.25	6601-7200	C-2	F-2	7707.3	> 7200	C-1
B-4	6274.88	6001-6600	C-3	F-3	7276.46	> 7200	C-1
C-1	5968.93	5401-6000	C-4	F-4	6088.15	6001-6600	C-3
C-2	6761.41	6601-7200	C-2	G-1	5839.68	5401-6000	C-4
C-3	6643.5	6601-7200	C-2	G-2	7351.98	> 7200	C-1
C-4	5822.99	5401-6000	C-4	G-3	7265.18	> 7200	C-1
D-1	5954.97	5401-6000	C-4	G-4	5691.47	5401-6000	C-4
D-2	6382.79	6001-6600	C-3	H-1	4998.29	< 5400	C-5
D-3	6988.89	6601-7200	C-2	H-2	6076.19	6001-6600	C-3
D-4	6042.2	6001-6600	C-3	H-3	5985.54	5401-6000	C-4
E-1	6473.72	6001-6600	C-3	H-4	4894.6	< 5400	C-5

As clearly shown on table 5-56, the column grouped in to five groups based on their base axial force; C-1 for axial force greater than 7200 KN, C-2 for axial force ranges between 6601 to 7200 KN, C-3 for axial force ranges between 6001 to 6600 KN, C-4 for axial force ranges between 5401 to 6000 KN and C-5 for axial force less than 5400 KN. In the interval the maximum axial force is taken for foundation design as shown in the table below.

Table C.55 Maximum axial force in each column group for G+12 with C-40 concrete

Interval	**P_{max} (KN)**	**Location of P_{max}**	**Group**	**No Member**
< 5400	4998.293	H-1	C-5	2
5401-6000	5985.54	H-3	C-4	6
6001-6600	6555.88	B-2	C-3	11
6601-7200	6988.89	D-3	C-2	6
> 7200	7707.3	F-2	C-1	5

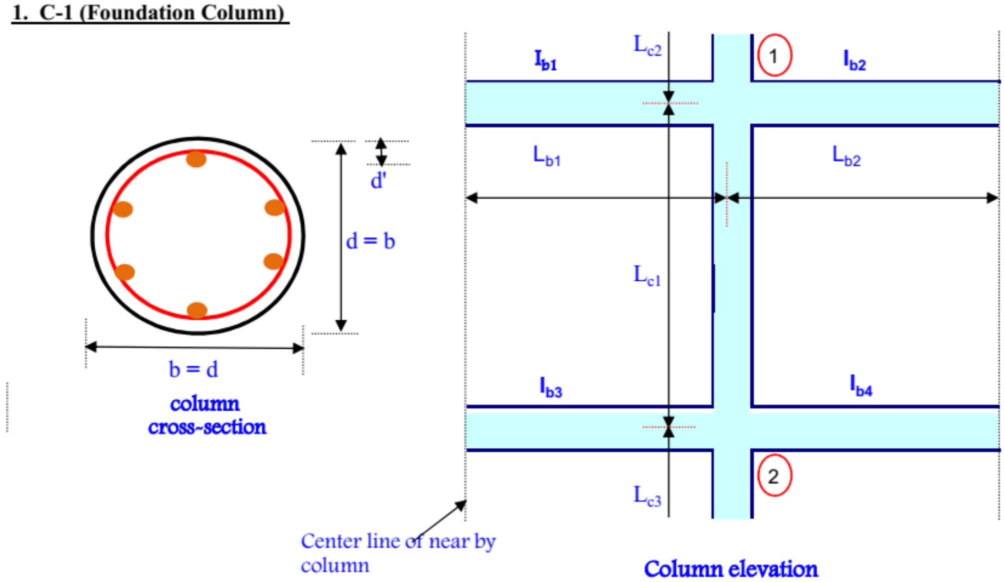
DESIGN OF CIRCULAR COLUMN BASED ON ES EN:2015

SAMPLE COLUMN DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building **Date:** 28-May-18

Description: Design of Column for G+12 Building (C-40) **Design by:** Yohannes Sefiw

1. C-1 (Foundation Column)



2. Material constant

Concrete - Grade C- 40 Steel - Grade S- 300

f_{ck}	32000	kpa	$f_{ck} = 0.8f_{cu}$	F_{yk}	300000	kpa
f_{ctk}	2116.6674	kpa	$f_{ctk} = 0.21f_{ck}^{2/3}$	γs	1.15	
γc	1.5			F_{yd}	260,870	kpa
f_{cd}	18133.333	kpa	$f_{cd} = 0.85f_{ck}/\gamma_c$	E_s	200,000	kpa
f_{ctd}	1411.1116	kpa	$f_{ctd}=f_{ctk}/\gamma_c$	$A_{s\ (min)}$	0.0035	m^2
E_{cm}	32489.543	kpa	$E_{cm} = 9.5(f_{ck}+8)^{1/3}$	$A_{s\ (max)}$	0.035325	m^2

3. Analysis Result:

Axial (kN)	Mom. x-x	Mom y-y
7627.12	433.95	531.21
7707.30	790.63	874.06

4. Structure Classification:

Second-order global elastic analysis was done. Therefore both sway and non-sway are taken care of.

5. Dimensions in x-x direction:

Item	Depth	Width
B_1 =	0.40	0.30
B_2 =	0.40	0.30
B_3 =	0.40	0.30
B_4 =	0.40	0.30
C_1 =	0.75	0.75
C_2 =	0.75	0.75
C_3 =	0.75	0.75

L_{b1} =	5.50
L_{b2} =	6.00
L_{c1} =	3.20
L_{c2} =	3.20
L_{c3} =	1.50

6. Dimensions in y-y direction:

Item	Depth	Width
B_1 =	0.40	0.30
B_2 =	0.40	0.30
B_3 =	0.40	0.30
B_4 =	0.40	0.30
C_1 =	0.75	0.75
C_2 =	0.75	0.75
C_3 =	0.75	0.75

L_{b1} =	6.00
L_{b2} =	6.00
L_{c1} =	3.20
L_{c2} =	3.20
L_{c3} =	1.50

7. Limits of Slenderness:

$$\lambda \le 50 - 25\left(\frac{M_1}{M_2}\right)$$

$\frac{M_1}{M_2}$ = 0.55 $\qquad$ $\frac{M_1}{M_2}$ = 0.61

$\lambda \le$ 36.28 $\qquad$ $\lambda \le$ 34.81

But, the slenderness ratio is:

$$\grave{\imath} = \frac{L_e}{i} \qquad i = \text{Radius of gyration} = \sqrt{\frac{I_g}{A_g}}$$

A_g = 0.442 m^2

I_g = 0.01552 m^4

i = 0.188

L_e = Effective buckling length

8. Effective Buckling Length:

$$L_e = \frac{\alpha_m + 0.4}{\alpha_m + 0.8} L \ge 0.7L$$

$$\alpha_m = \frac{\alpha_1 + \alpha_2}{2}$$

$$\alpha_1 = \frac{I_{c1}/L_{c1} + I_{c2}/L_{c2}}{I_{b1}/L_{b1} + I_{b2}/L_{b2}}$$

$$\alpha_2 = \frac{I_{c1}/L_{c1} + I_{c3}/L_{c3}}{I_{b3}/L_{b3} + I_{b4}/L_{b4}}$$

About x-x direction.				About y-y direction.			
I_{c1} =	0.01552	I_{c1} =	0.01552	I_{c1} =	0.01552	I_{c1} =	0.01552
I_{c2} =	0.01552	I_{c3} =	0.01552	I_{c2} =	0.01552	I_{c3} =	0.01552
I_{b1} =	0.00160	I_{b3} =	0.00160	I_{b1} =	0.00160	I_{b3} =	0.00160
I_{b2} =	0.00160	I_{b4} =	0.00160	I_{b2} =	0.00160	I_{b4} =	0.00160
α_1 =	**17.401**	α_2 =	**27.261**	α_1 =	**18.192**	α_2 =	**28.501**
	α_m =	**22.331**			α_m =	**23.346**	

- the effective buckling length:

L_e = **3.145** $\qquad$ L_e = **3.147**

- Slenderness ratio:

ì = **16.772** **Not Slender** **Ignore Secondary Effects** | ì = **16.784** **Not Slender** **Ignore Secondary Effect**

9. Design Actions:

Calculate Eccentricities in the x-x Direction

Total = $e_{tot} = e_e + e_a + e_2$

$e_e = \max \text{ of } \begin{cases} 0.6e_{02} + 0.4e_{01} \\ 0.4e_{02} \end{cases}$

$e_{01} = 0.0569$

$e_{02} = 0.1026$

$e_e =$ **0.0843** m

$e_a = \frac{L_e}{300} \geq 200mm$

$e_a =$ **0.02** **m**

$e_2 =$ **0.00** **m**

$e_{tot} =$ **0.1043** **m**

$N_{sd} =$ **7707.30** **kN**

$M_{sd\ x\text{-}x} =$ **803.93** **kN-m**

Calculate Eccentricities in the y-y Direction

Total = $e_{tot} = e_e + e_a + e_2$

$e_e = \max \text{ of } \begin{cases} 0.6e_{02} + 0.4e_{01} \\ 0.4e_{02} \end{cases}$

$e_{01} = 0.0696$

$e_{02} = 0.1134$

$e_e =$ **0.0959**

$e_a = \frac{L_e}{300} \geq 200mm$

$e_a =$ **0.02** **m**

$e_2 =$ **0.00** **m**

$e_{tot} =$ **0.1159** **m**

$M_{sd\ y\text{-}y} =$ **893.30** **kN-m**

Figure C.42 Sample column design for G+12 building C-40 concrete

C.5.2.3.5 SAMPLE FOUNDATION DESIGN FOR G+12 BUILDING WITH C-25 CONCRETE

Following similar procedure as sample foundation design of G+2 building, sample foundation design for G+12 building is done as shown below.

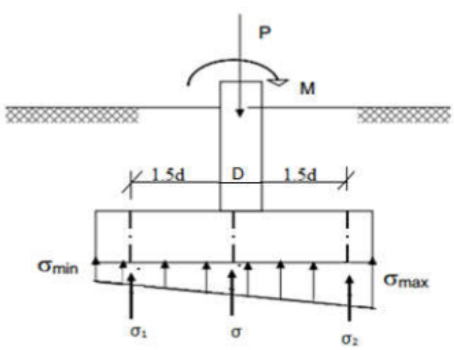
DESIGN OF SQUARE ISOLATED FOUNDATION BASED ON ES EN:2015

SAMPLE FOUNDATION DESIGN TO INVESTIGATE EFFECT OF CONCRETE GRADE ENHANCER ADMIXTURE ON STRUCTURAL DESIGN OF HIGH RISE BUILDING

Building Type: Mixed Use Building Date: 28-May-18

Description: Design of Square Isolated Foundation for G+12 Building (C-40) Design by: Yohannes Sefiw

1. Foundation 1 (F-1)



2. Material Constant

Concrete Grade C- 40

f_{ck} = 32,000.000000 kpa

f_{ctk} = 2,116.667364 kpa

γc = 1.50

f_{cd} = 18,133.333333 kpa

f_{ctd} = 1,411.111576 kpa

E_{cm} = 32,489.542987 kpa

Steel Grade S- 300

f_{yk} = 300,000.0000 Kpa

γs = 1.15

f_{yd} = 260,869.5652 Kpa

E_s = 200,000.0000 Kpa

Cover, C (mm) = 50

3. Soil Property

Ground Type - Dense sand

Facter of Safety, Fs = 2.00

$\sigma_{ult} = F_s . \sigma_{al}$ Allowble soil bearing capacity, σ_{all} = 420 Kpa

Ultimate Soil bearing capacity, σ_{ult} = **840** kpa

4. Proportioning

$A = B^2 = P/\sigma_{all,}$ $B = \sqrt{P/\sigma all}$ Axial force, P (KN) = 7707.30

Foundation Width, B (m) = **4.28**

Provided Foundation Width, B (m) = **4.30**

5. Contact pressure

$\sigma_{max} = \frac{P}{A}\left(1 + 6\frac{e_x}{B} + 6\frac{e_y}{B}\right) \leq \sigma_{ult}$ $\sigma_{min} = \frac{P}{A}\left(1 - 6\frac{e_x}{B} - 6\frac{e_y}{B}\right)$ $e_x = \frac{M_x}{P}$ $e_y = \frac{M_y}{P}$

M_x (KNm) = 808.58 e_x (m) = 0.1049 σ_{max} (Kpa) = 544.21 Area, A(m^2) = 18.49

M_y (KNm) = 879.27 e_y (m) = 0.1141 σ_{min} (Kpa) = 289.46 **Status - Ok! Area is adequate**

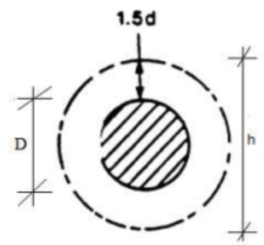
6. Foundation Thickness

Thickness, d (m) = **1.05** Column Diameter, D (m) = 0.75

6.1 Check trial foundation thickness for punching shear

The punching shear resistance, $V_{Rd1} = 0.25f_{ctd}.K1.K2.U.d$, $K_1 = 1+50\rho \leq 2$ $K_2 = 1.6\text{-}d \geq 1$

$U = \Pi.h = \Pi\,(1.5d+D+1.5d) = \Pi\,(3d+D)$ For circular column Developed shear, $V_1 = \sigma A$, $\sigma = \frac{\sigma 1+\sigma 2}{2}$



$\sigma_1 = \sigma_{min} + \frac{(\frac{B-3d-D}{2})(\sigma_{max}-\sigma_{min})}{B}$ $\sigma_2 = \sigma_{min} + \frac{(\frac{B+3d+D}{2})(\sigma_{max}-\sigma_{min})}{B}$

Net developed shear, $V_{d1} = P\text{-}V_1$ $\rho_{min} = 0.5/f_{yk}$ $A = \frac{\Pi}{4}(3d+D)^2$

The thickness is sufficient for punching shear if $V_{Rd1} > V_{d1}$ A (m^2) = 11.940

ρ_{min} = 0.0017 K_2 = 1.00 V_{Rd1} (KN) = **4916.63** V_{d1} (KN) = **2730.34**

U (m) = 12.25 K_1 = 1.08 V_1 (KN) = 4976.96

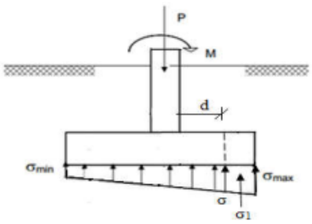
σ_1 (Kpa) = 301.31 σ_2 (Kpa) = 532.361 σ (Kpa) = 416.836

Status - Ok! Thickness is adequate for punching shear

6.2 Check trial foundation thickness for wide beam shear

The wide beam shear resistance, $V_{Rd2} = 0.25f_{ctd}k_1k_2bd$ Developed wide beam shear, $V_{d2} = \sigma_1 A$, $\sigma_1 = \frac{\sigma+\sigma max}{2}$

The thickness is sufficient for wide beam shear if $V_{Rd2} > V_{d2}$ $A = B\,\frac{B-D-2d}{2}$ $\sigma = \sigma_{min} + \frac{(\frac{B+2d+D}{2})(\sigma_{max}-\sigma_{min})}{B}$



V_{Rd2} (KN) = **1725.52** σ (Kpa) = 501.258 σ_1 (Kpa) = 522.734 A (m^2) = 3.12

V_{d2} (KN) = **1629.62**

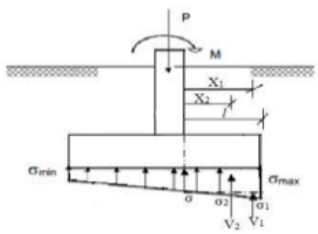
Status - Ok! Thickness is adequate for wide beam shear

6.3. Check trial foundation thickness for bending moment

Developed moment, $M_{sd} = \sum\sigma.A.x = V_1X_1 + V_2X_2$ $V_1 = \sigma_1 l$ $V_2 = \sigma_2 l$

$l = \frac{1}{2}(B-D)$ $X_2 = \frac{1}{2}l$ $X_1 = \frac{2}{3}l$ $\sigma = \sigma_{min} + \frac{(\frac{B+D}{2})(\sigma_{max}-\sigma_{min})}{B}$

The concrete moment capacity, $M = 0.32f_{cd}bd^2$ $\sigma_1 = \frac{\sigma_{max}-\sigma}{2}$



l = 1.775 X_2 = 0.888 X_1 = 1.183 $\sigma_2 = \sigma$

σ (Kpa) = 439.052 σ_1 (Kpa) = 52.579 σ_2 (Kpa) = 439.052

V_1 (KN/m) = 93.3271 V_2 (KN/m) = 779.318 M_{sd} (KN-m/m) = **802.082**

M (KN-m/m) = **6397.44**

Status - Ok! The thickness is adequate for bending moment

7. Reinforcement Calculation

$A_s = \rho bd$ $\rho = \frac{fcd}{fyd}\left[1 - \sqrt{1 - \frac{2Msd}{fcdbd^2}}\right]\rho_{min}$ Spacing, $S = \frac{ba_s}{A_s}$

ρ = 0.0028 A_s (mm^2) = **2989.46** **Ø = 24** S (mm) = **151.251**

Use Ø 24 C/C 150 mm

8. Development length

l_d (mm) = **1109.21** $l = \frac{B-D}{2}$ - Cover $l_{d,\,avl}$ (mm) = **1725**

$l_d = \frac{\phi fyd}{4fbd}$ $f_{bd} = f_{ctd}$ **Status - Bend the bars upward is not mandatory!**

Figure C.43 Sample foundation design for G+12 building with C-40 concrete

APPENDIX D - STRUCTURAL DETAILING

D.1 STRUCTURAL DETAILING FOR C-25 CONCRETE

D.1.1 STRUCTURAL DETAILING FOR G+2 BUILDING WITH C-25 CONCRETE

D.1.1.1 STAIRCASE DETAILING FOR G+2 BUILDING WITH C-25 CONCRETE

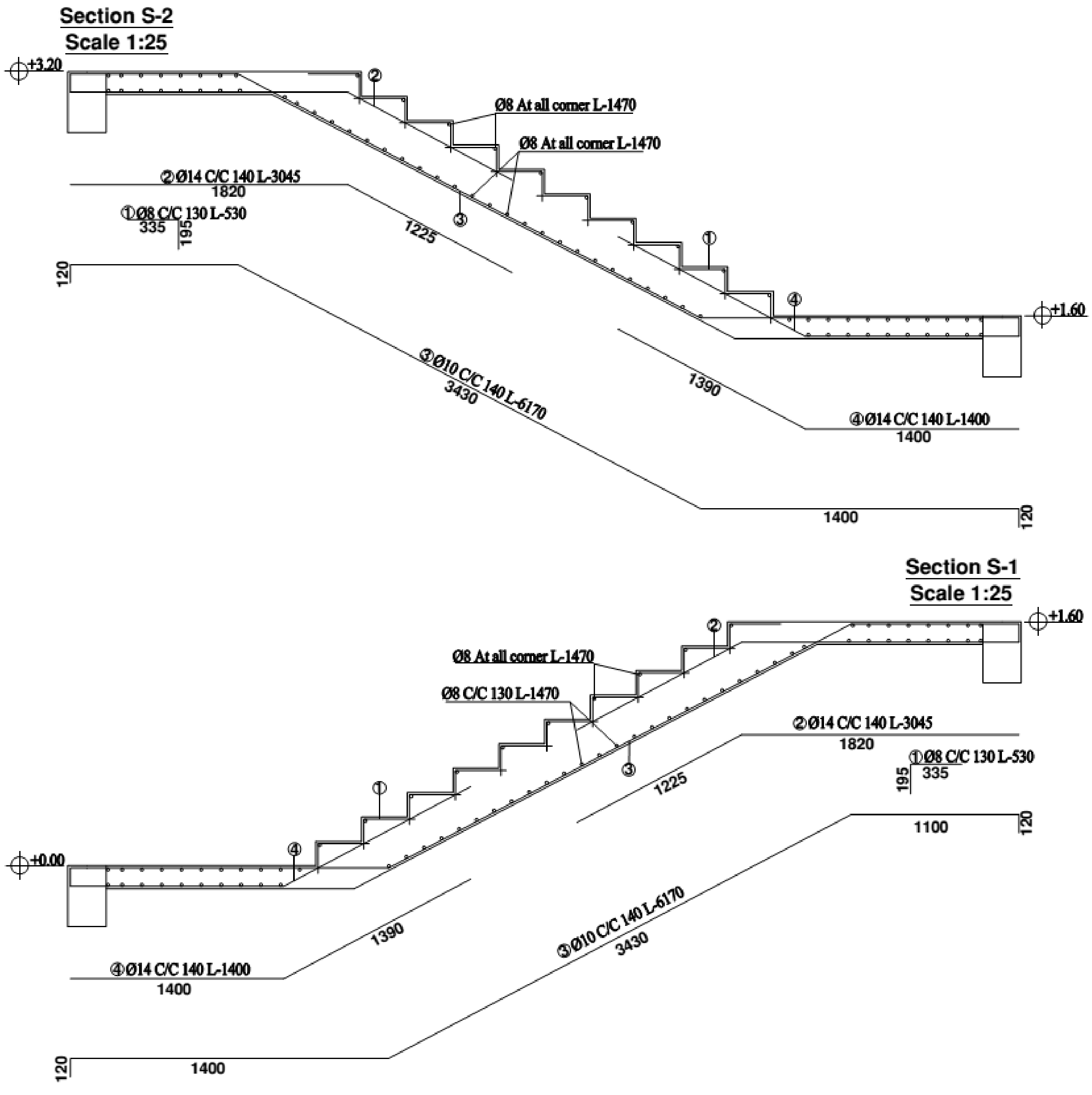


Figure D.1 Sample staircase detailing for G+2 building with C-25 concrete

D.1.1.2 SLAB DETAILING FOR G+2 BUILDING WITH C-25 CONCRETE

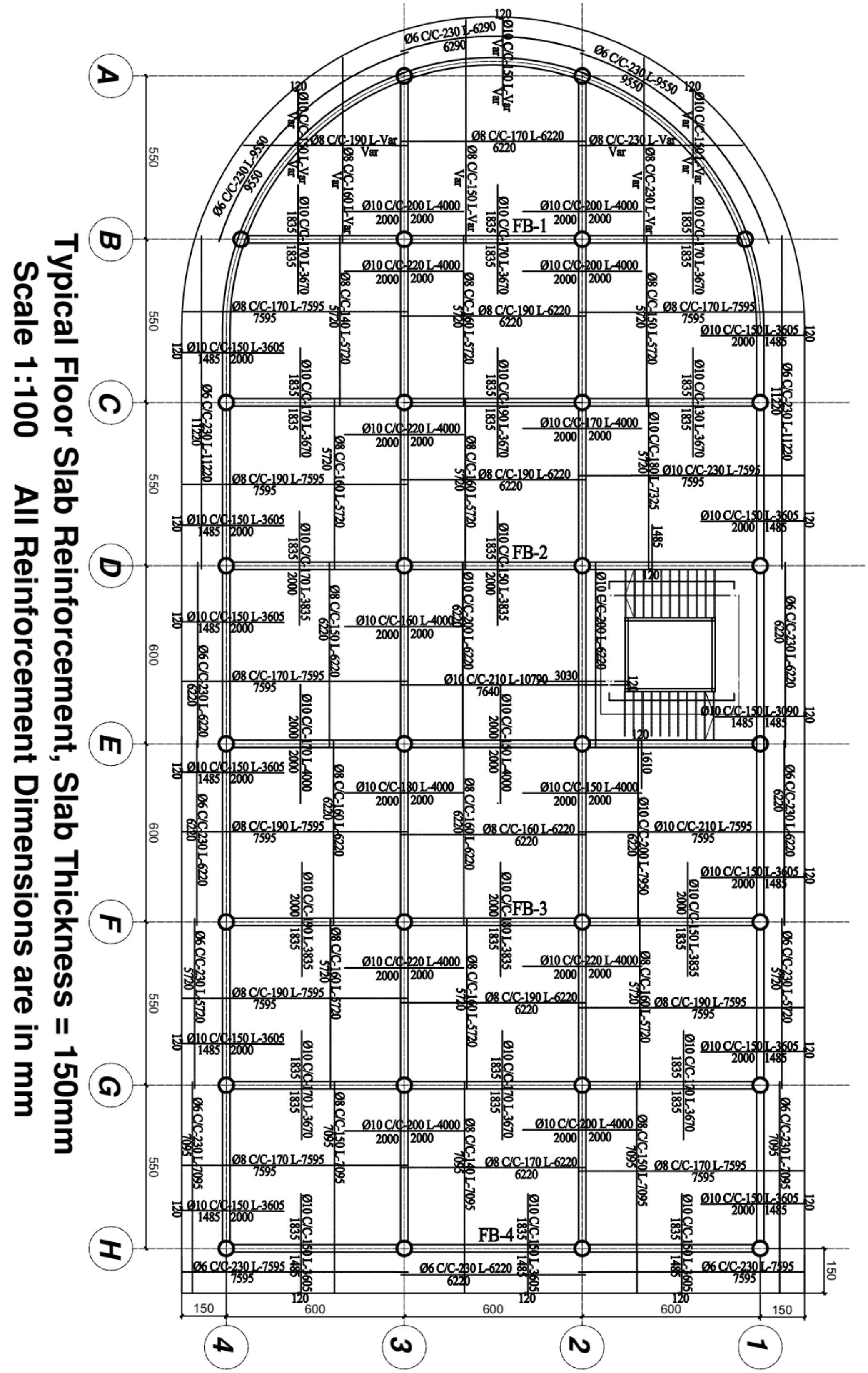


Figure D.2 Sample slab detailing for G+2 building with C-25 concrete

D.1.1.3 BEAM DETAILING FOR G+2 BUILDING WITH C-25 CONCRETE

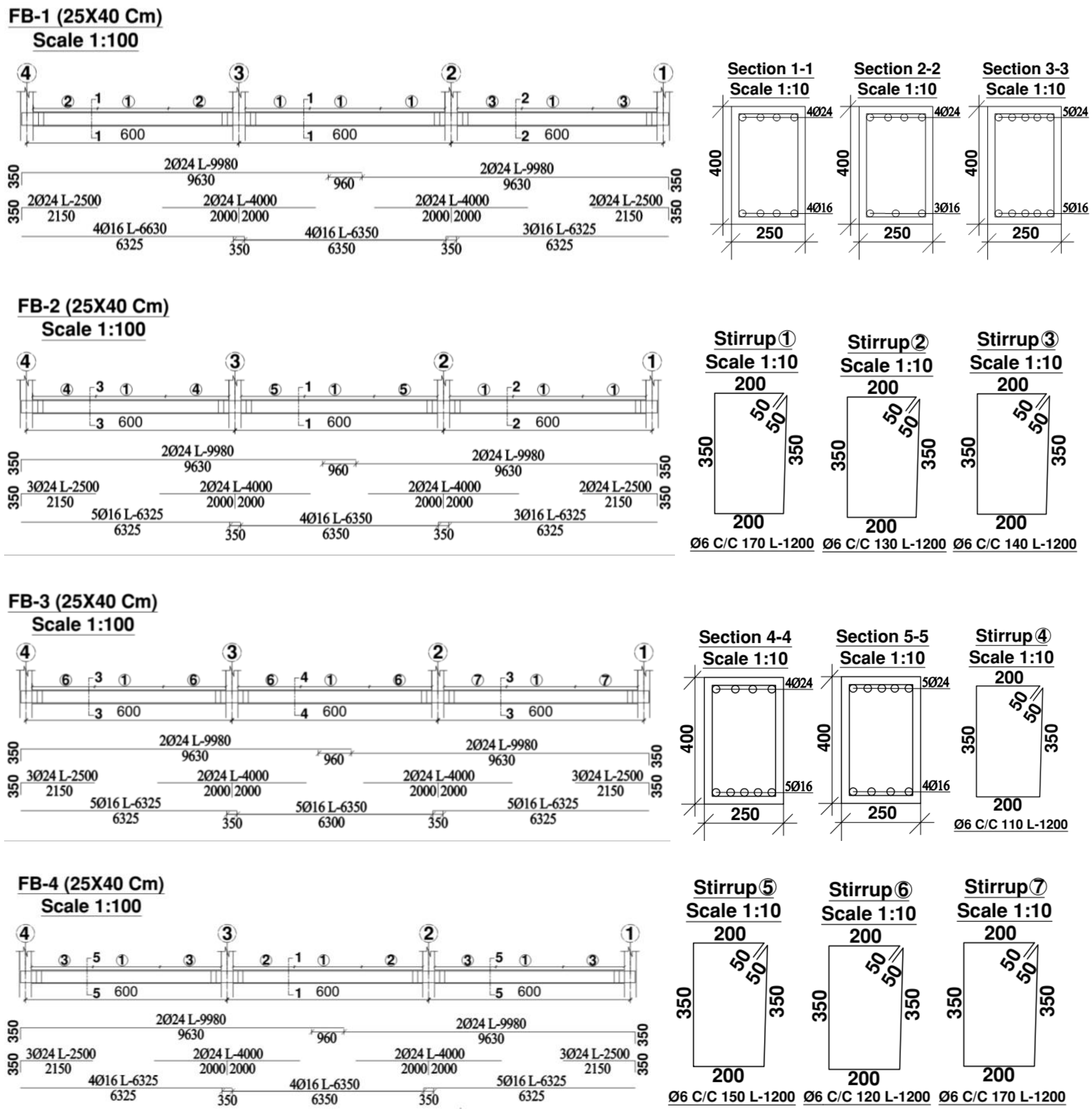


Figure D.3 Sample beam detailing for G+2 building with C-25 concrete

D.1.1.4 COLUMN DETAILING FOR G+2 BUILDING WITH C-25 CONCRETE

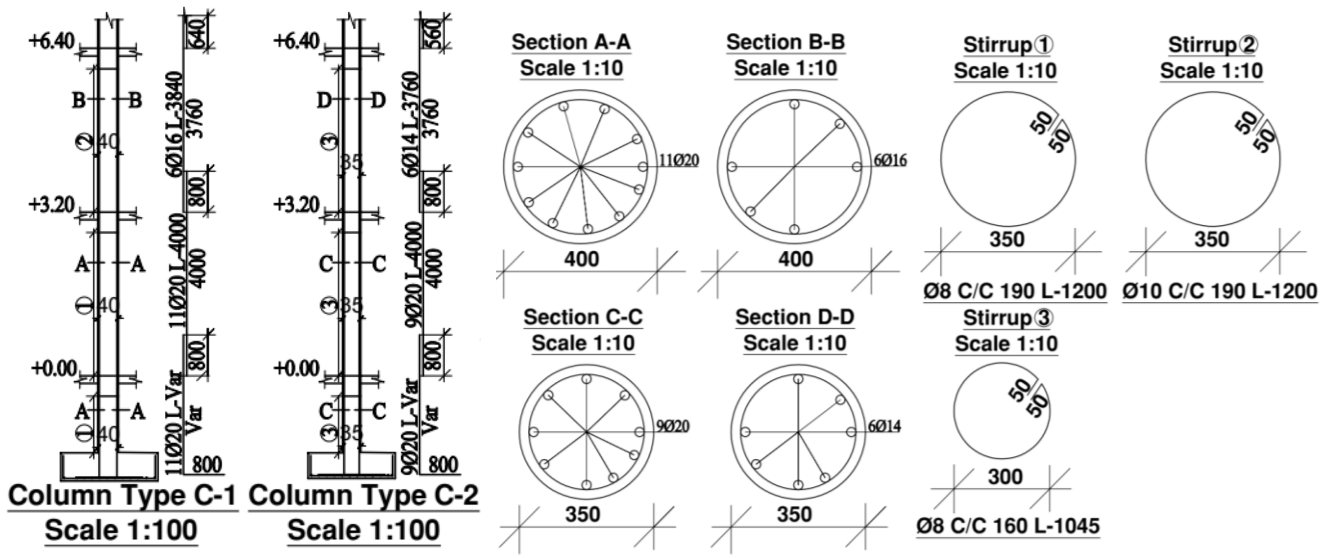


Figure D.4 Sample column detailing for G+2 building with C-25 concrete

D.1.1.5 FOUNDATION DETAILING FOR G+2 BUILDING WITH C-25 CONCRETE

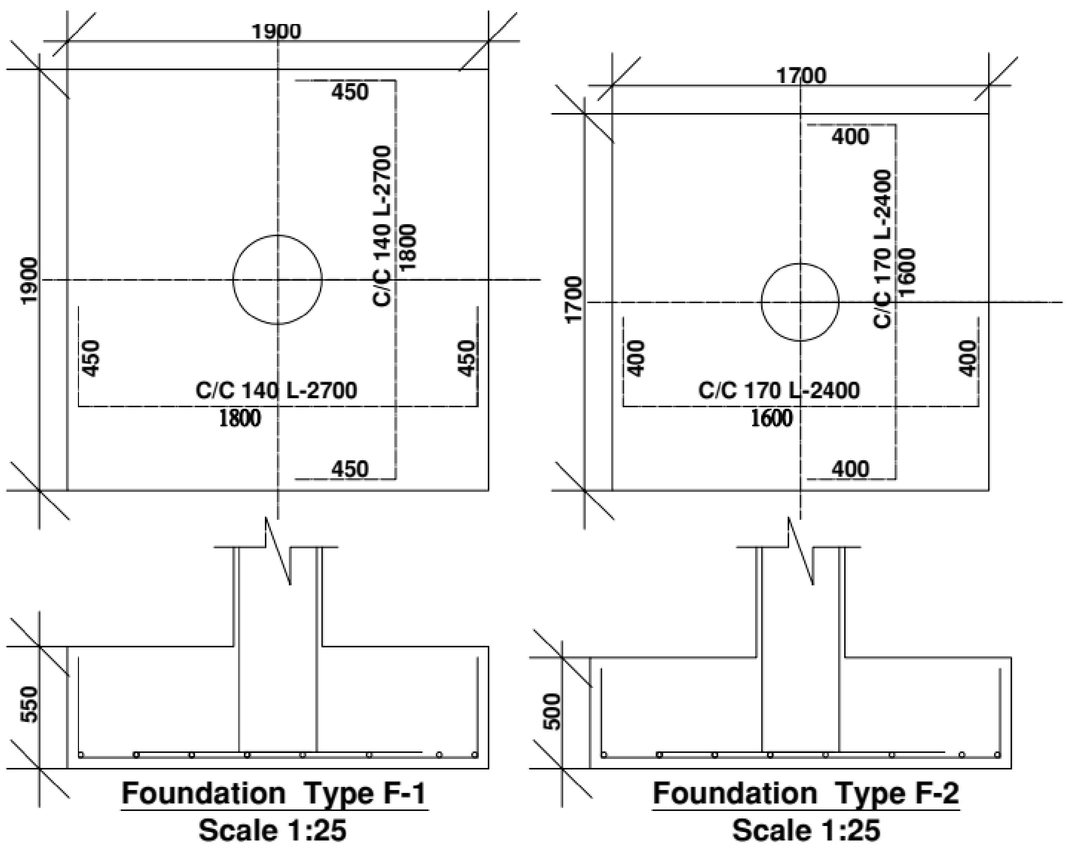


Figure D.5 Sample column detailing for G+2 building with C-25 concrete

D.1.2 STRUCTURAL DETAILING FOR G+7 BUILDING WITH C-25 CONCRETE

D.1.2.1 SLAB DETAILING FOR G+7 BUILDING WITH C-25 CONCRETE

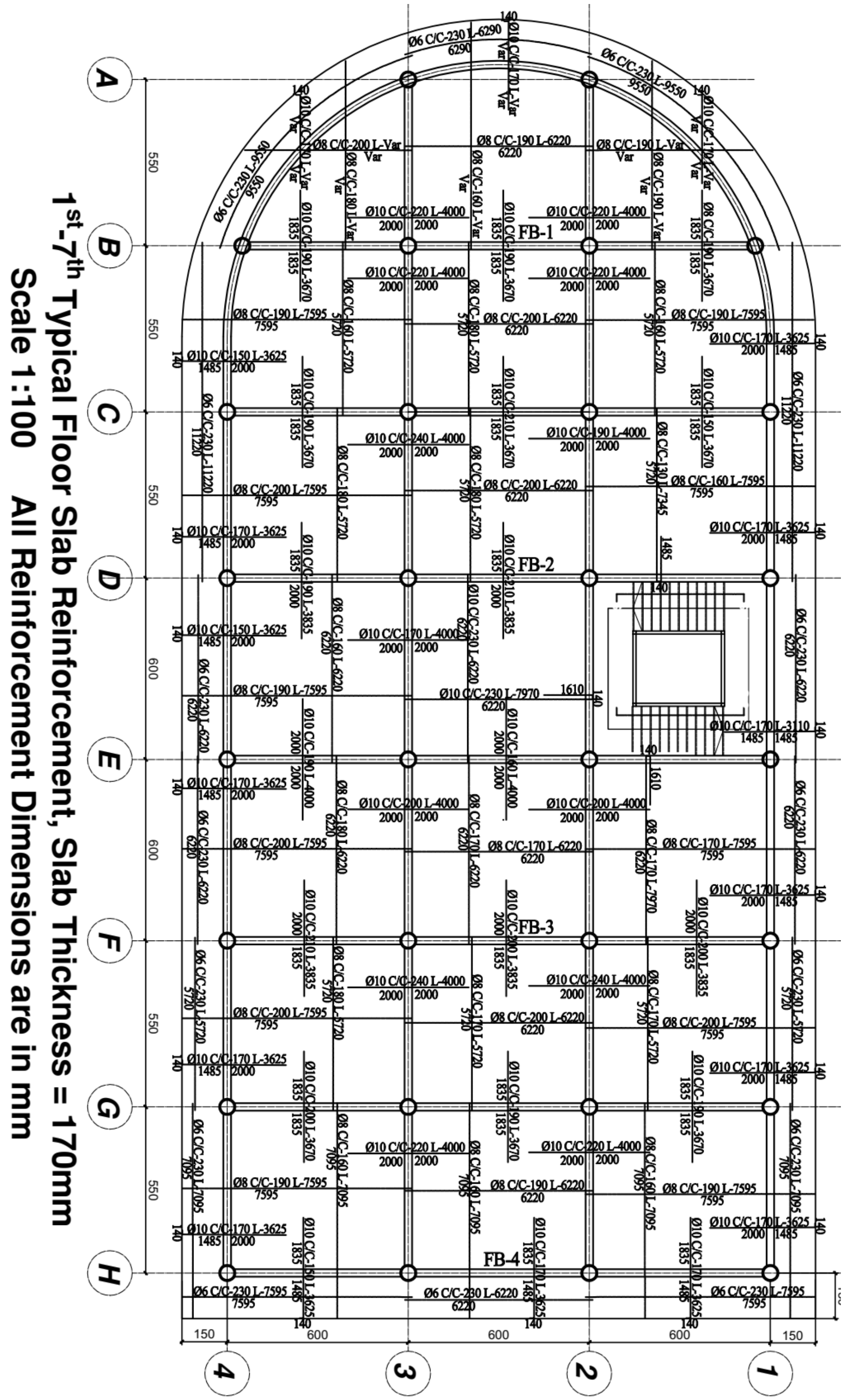


Figure D.6 Sample slab detailing for G+7 building with C-25 concrete

D.1.2.2 STAIRCASE DETAILING FOR G+7 BUILDING WITH C-25 CONCRETE

Sample staircase detailing for G+7 building is the same as sample staircase detailing for G+2 building.

D.1.2.3 BEAM DETAILING FOR G+7 BUILDING WITH C-25 CONCRETE

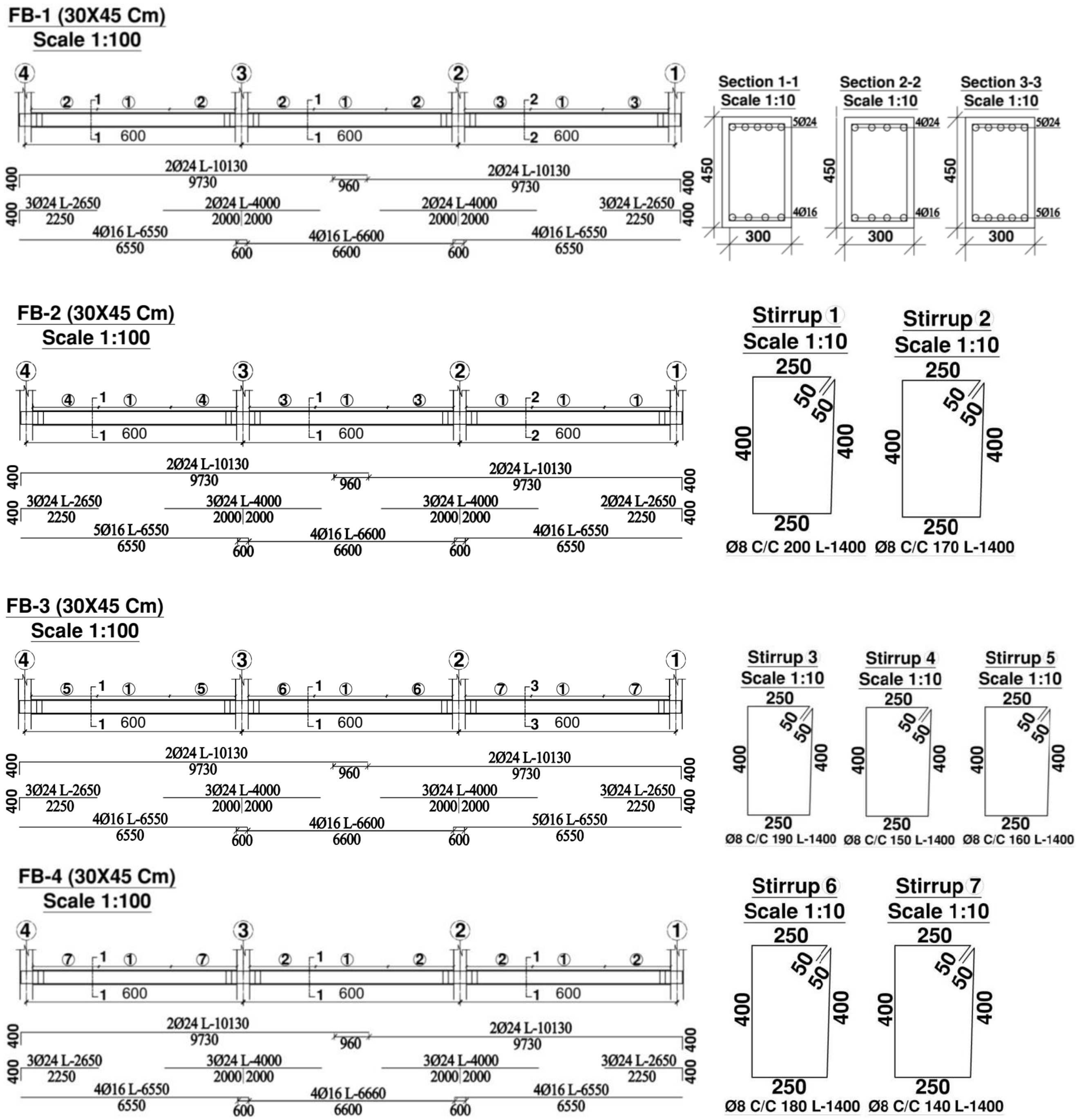


Figure D.7 Sample beam detailing for G+7 building with C-25 concrete

D.1.2.4 COLUMN DETAILING FOR G+7 BUILDING WITH C-25 CONCRETE

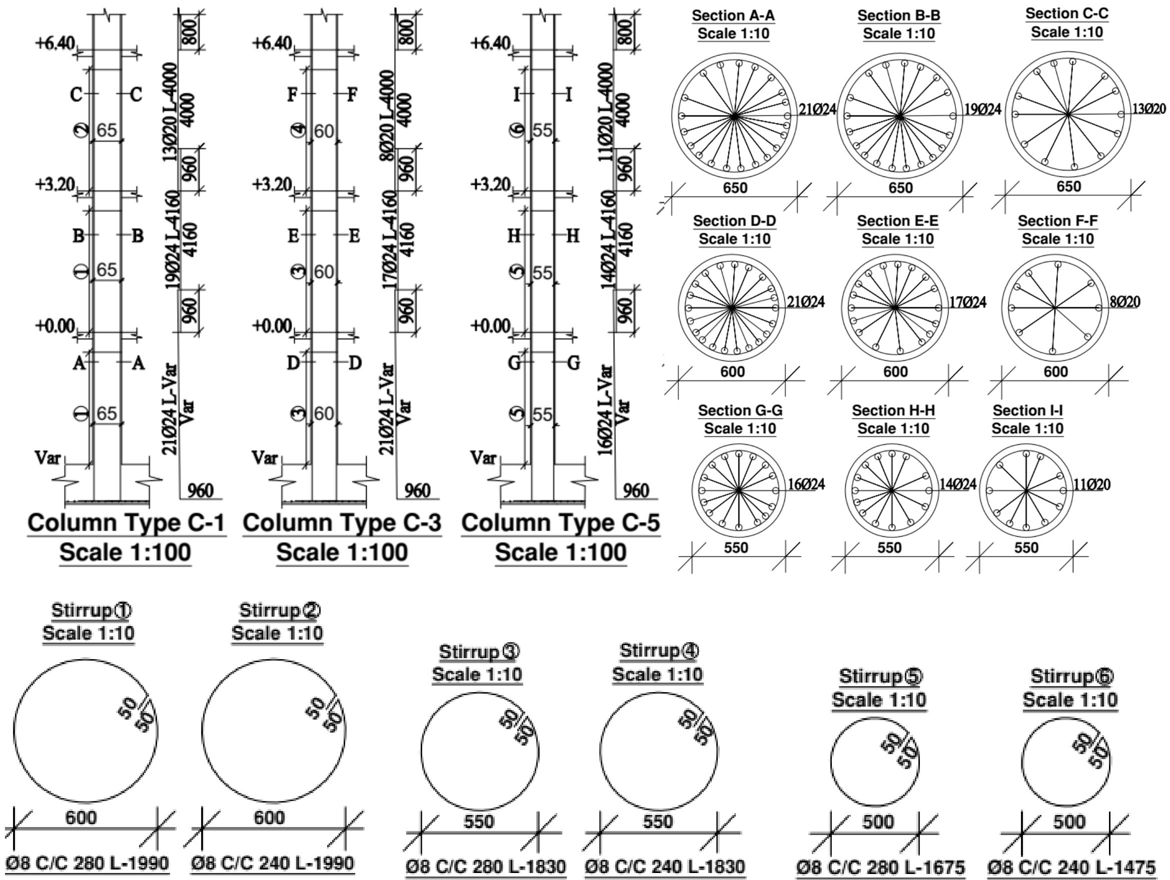


Figure D.8 Sample column detailing for G+7 building with C-25 concrete

D.1.2.5 FOUNDATION DETAILING FOR G+7 BUILDING WITH C-25 CONCRETE

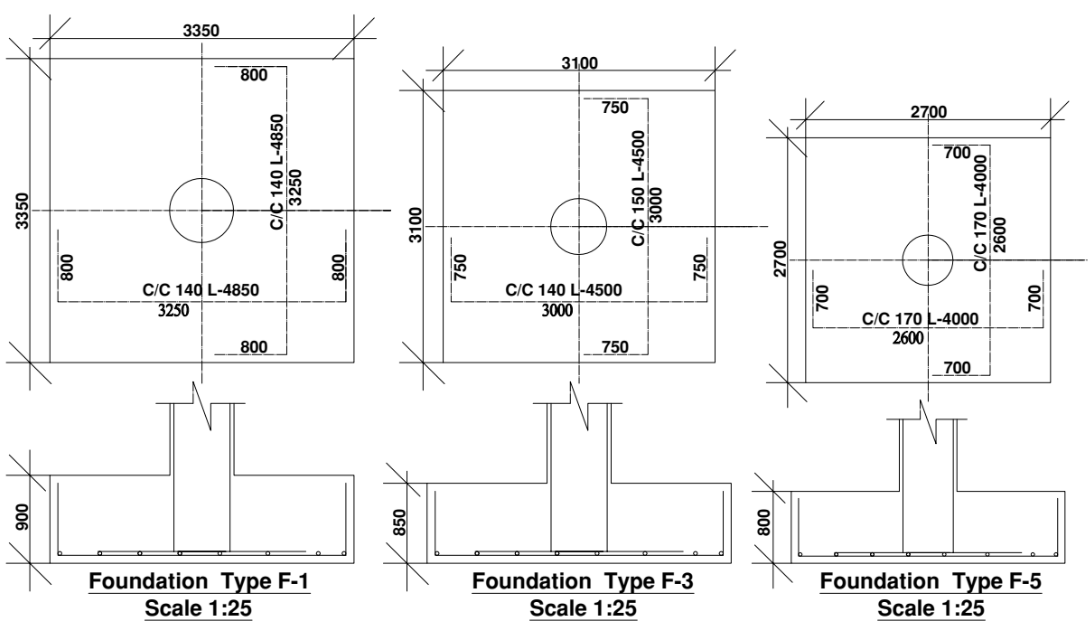


Figure D.9 Sample foundation detailing for G+7 building with C-25 concrete

D.1.3 STRUCTURAL DETAILING FOR G+12 BUILDING WITH C-25 CONCRETE

D.1.3.1 SLAB DETAILING FOR G+12 BUILDING WITH C-25 CONCRETE

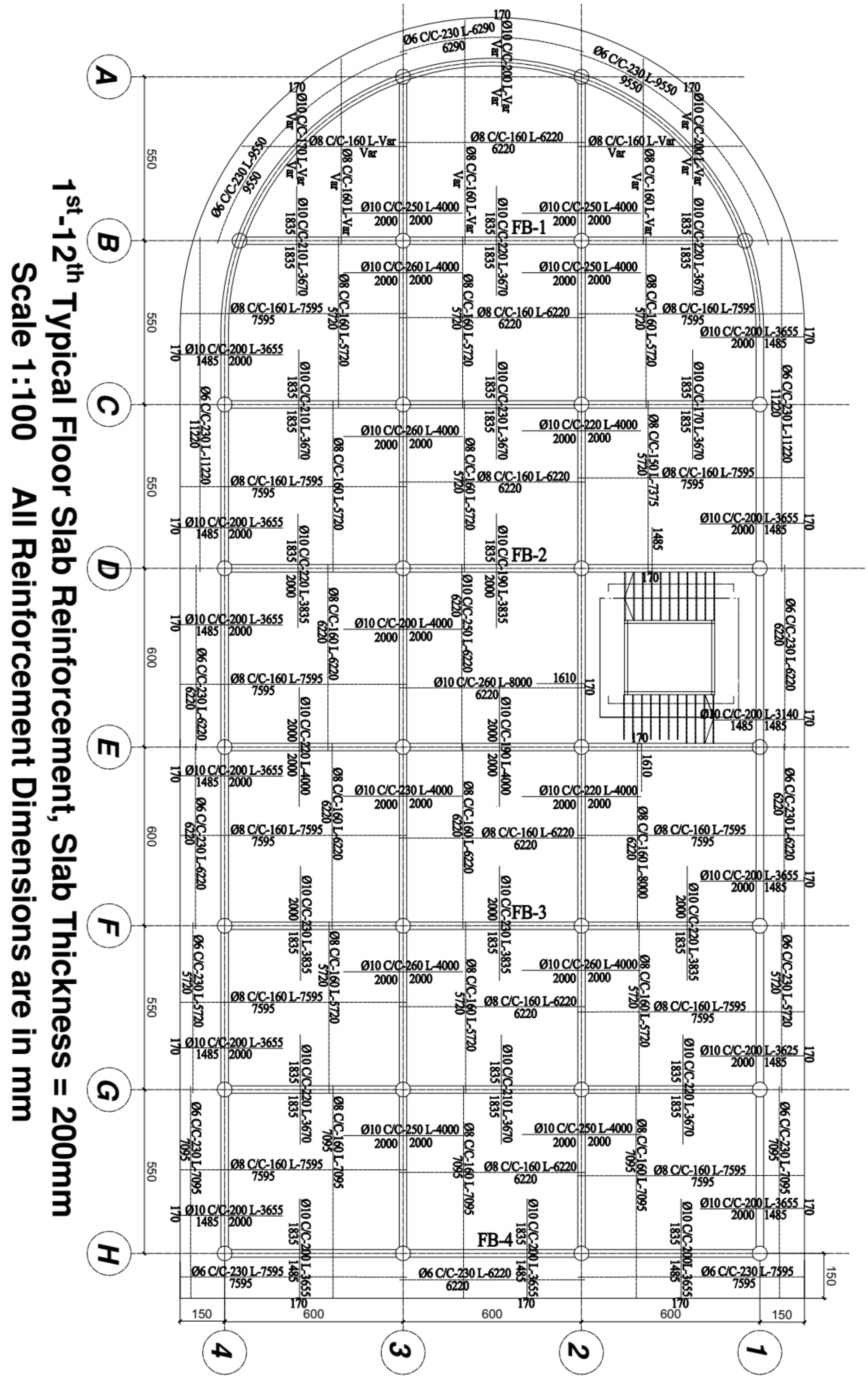


Figure D.10 Sample slab detailing for G+12 building with C-25 concrete

D.1.3.2 STAIRCASE DETAILING FOR G+12 BUILDING WITH C-25 CONCRETE

Sample staircase detailing for G+12 building is the same as sample staircase detailing for G+2 building.

D.1.3.3 BEAM DETAILING FOR G+12 BUILDING WITH C-25 CONCRETE

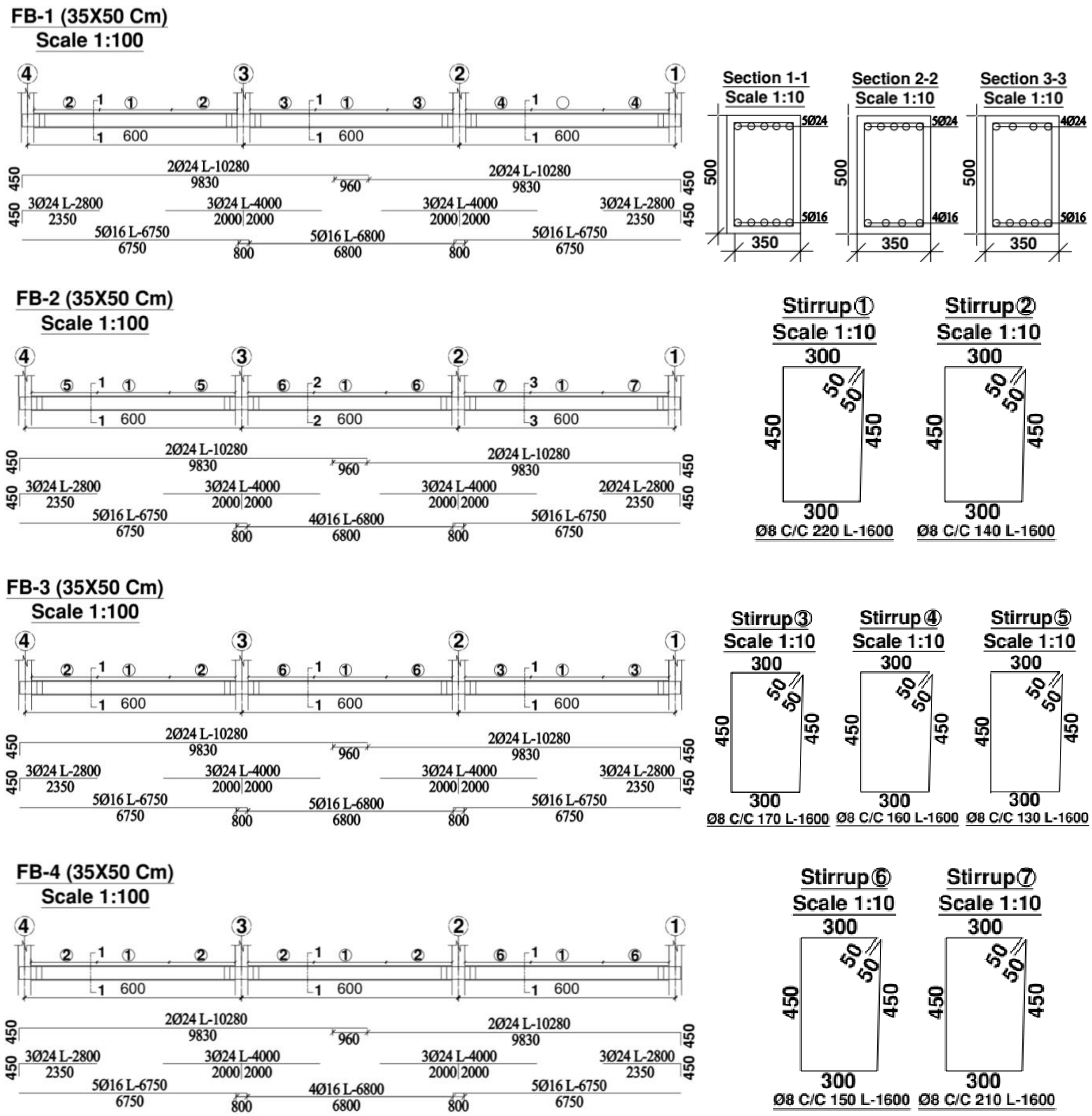


Figure D.11 Sample slab detailing for G+12 building with C-25 concrete

D.1.3.4 COLUMN DETAILING FOR G+12 BUILDING WITH C-25 CONCRETE

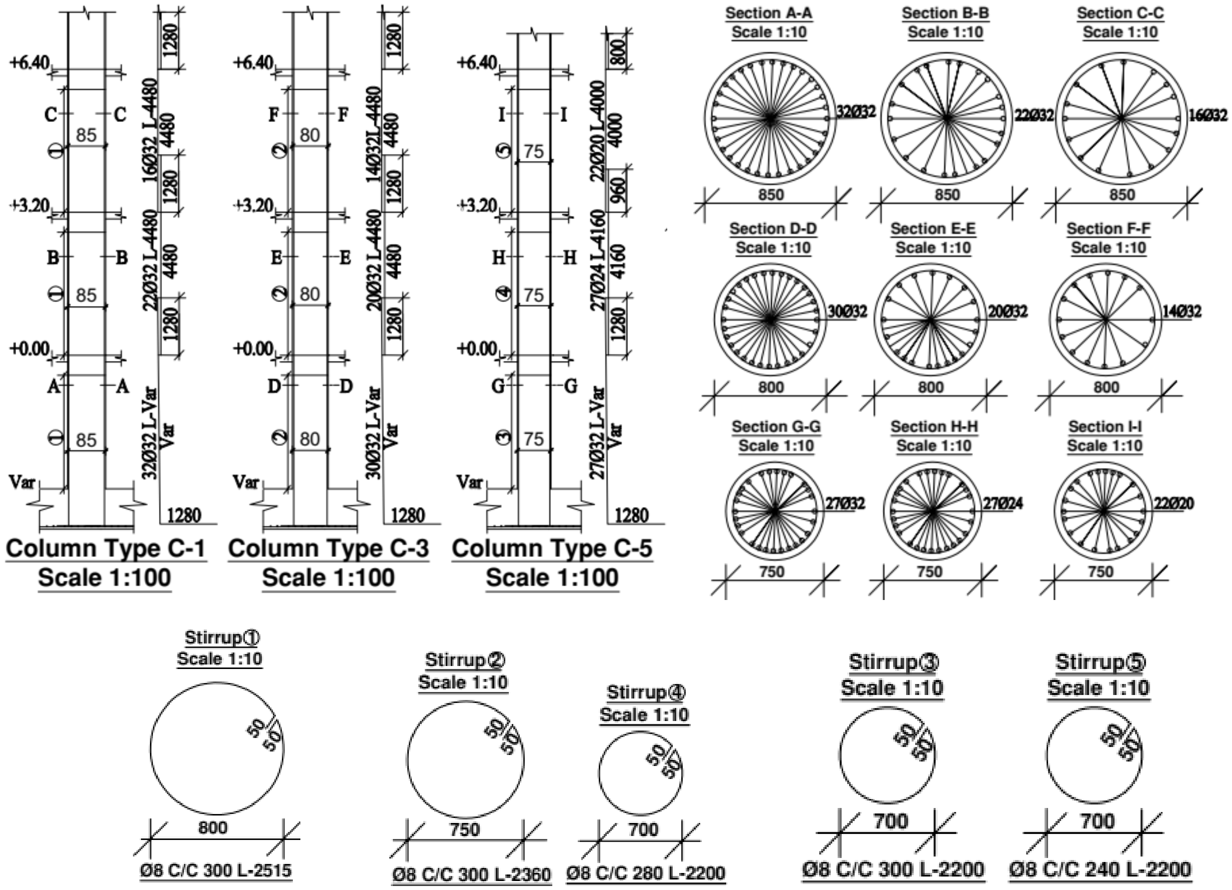


Figure D.12 Sample column detailing for G+12 building with C-25 concrete

D.1.3.5 FOUNDATION DETAILING FOR G+12 BUILDING WITH C-25 CONCRETE

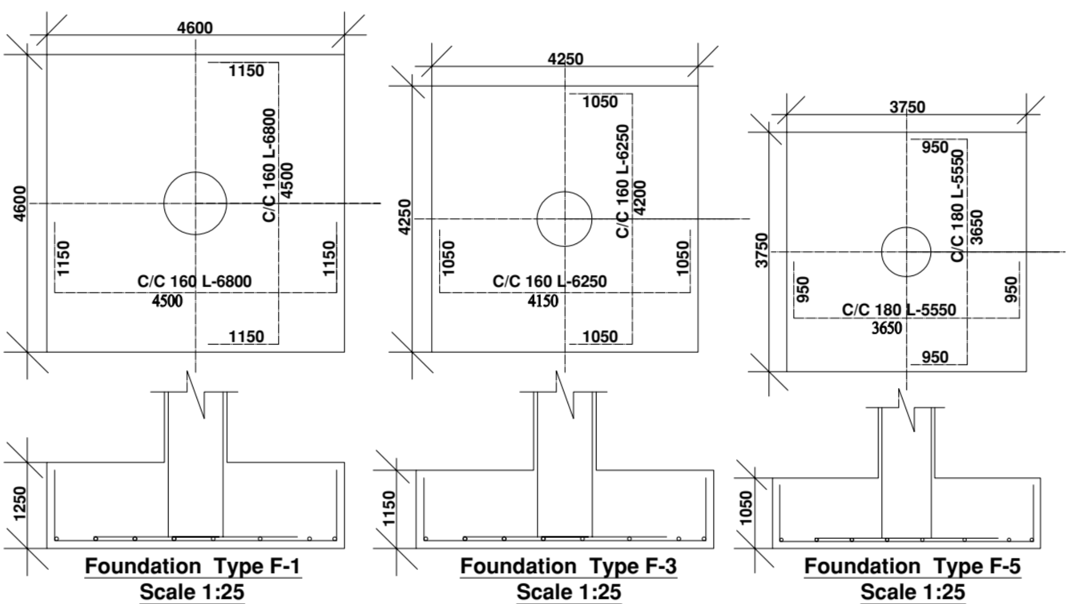


Figure D.13 Sample foundation detailing for G+12 building with C-25 concrete

D.2 STRUCTURAL DETAILING FOR C-40 CONCRETE

D.2.1 STRUCTURAL DETAILING FOR G+2 BUILDING WITH C-40 CONCRETE

D.2.1.1 STAIRCASE DETAILING FOR G+2 BUILDING WITH C-40 CONCRETE

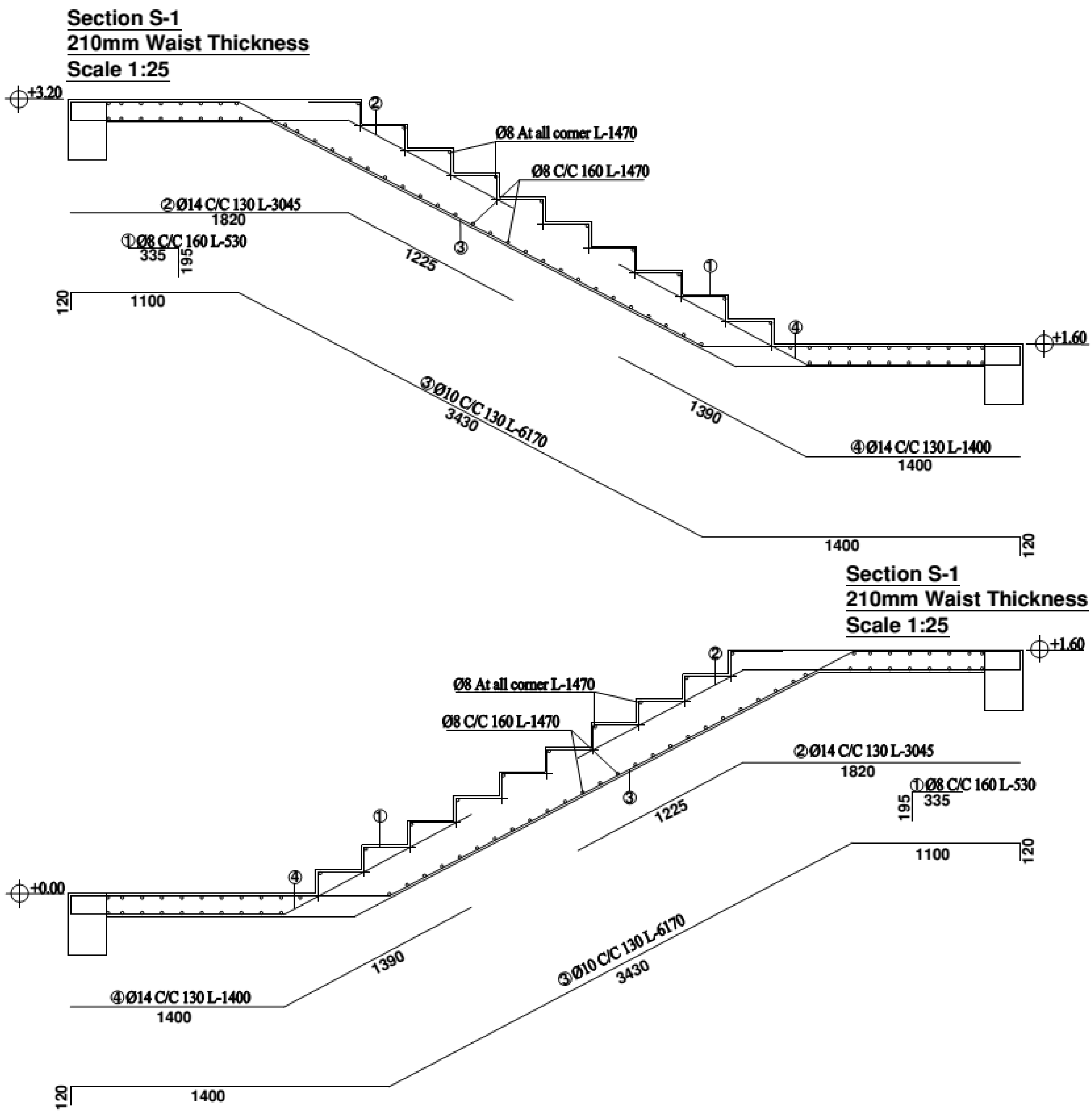


Figure D.14 Sample staircase detailing for G+2 building with C-40 concrete

D.2.1.2 SLAB DETAILING FOR G+2 BUILDING WITH C-40 CONCRETE

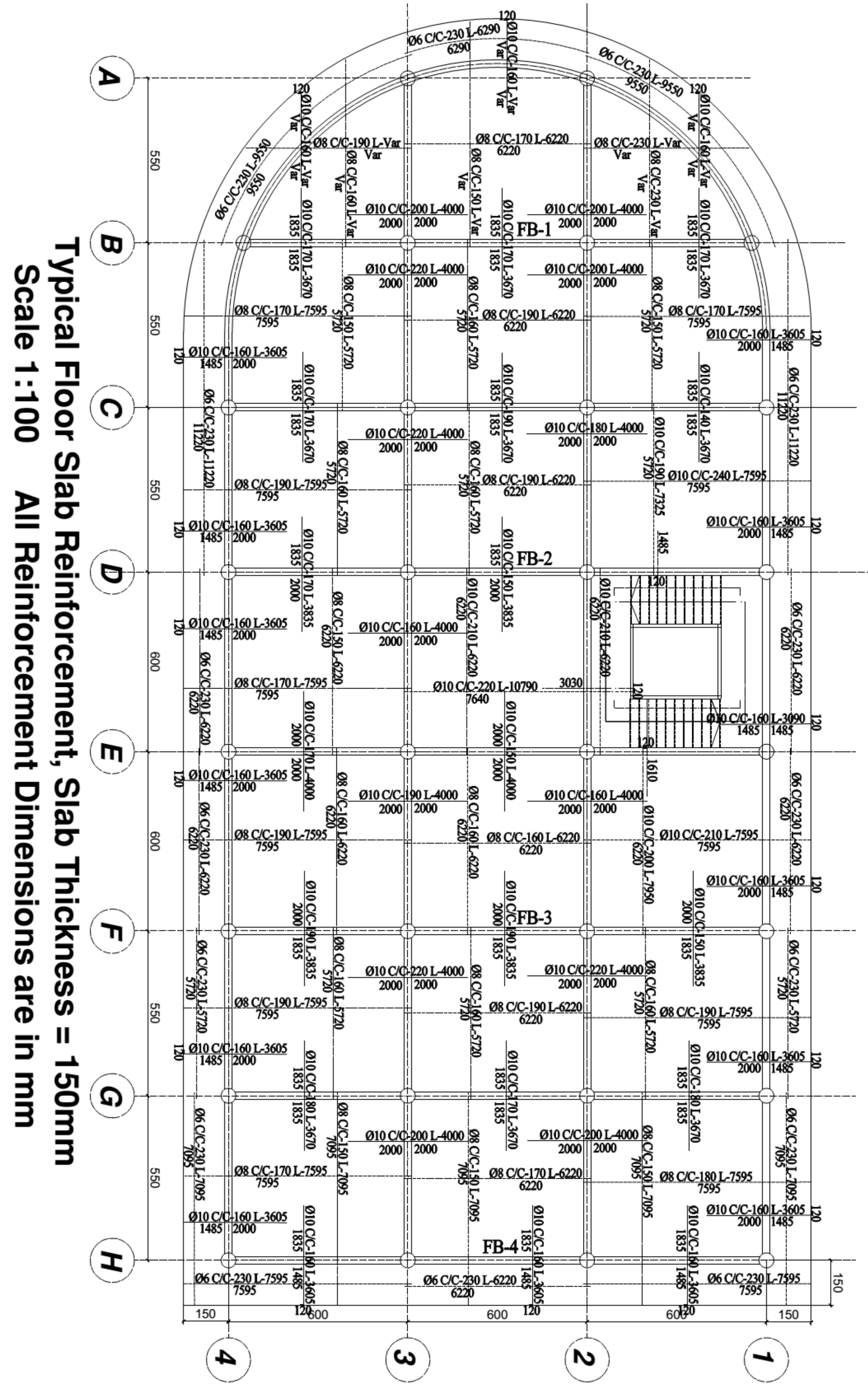


Figure D.15 Sample slab detailing for G+2 building with C-40 concrete

D.2.1.3 BEAM DETAILING FOR G+2 BUILDING WITH C-40 CONCRETE

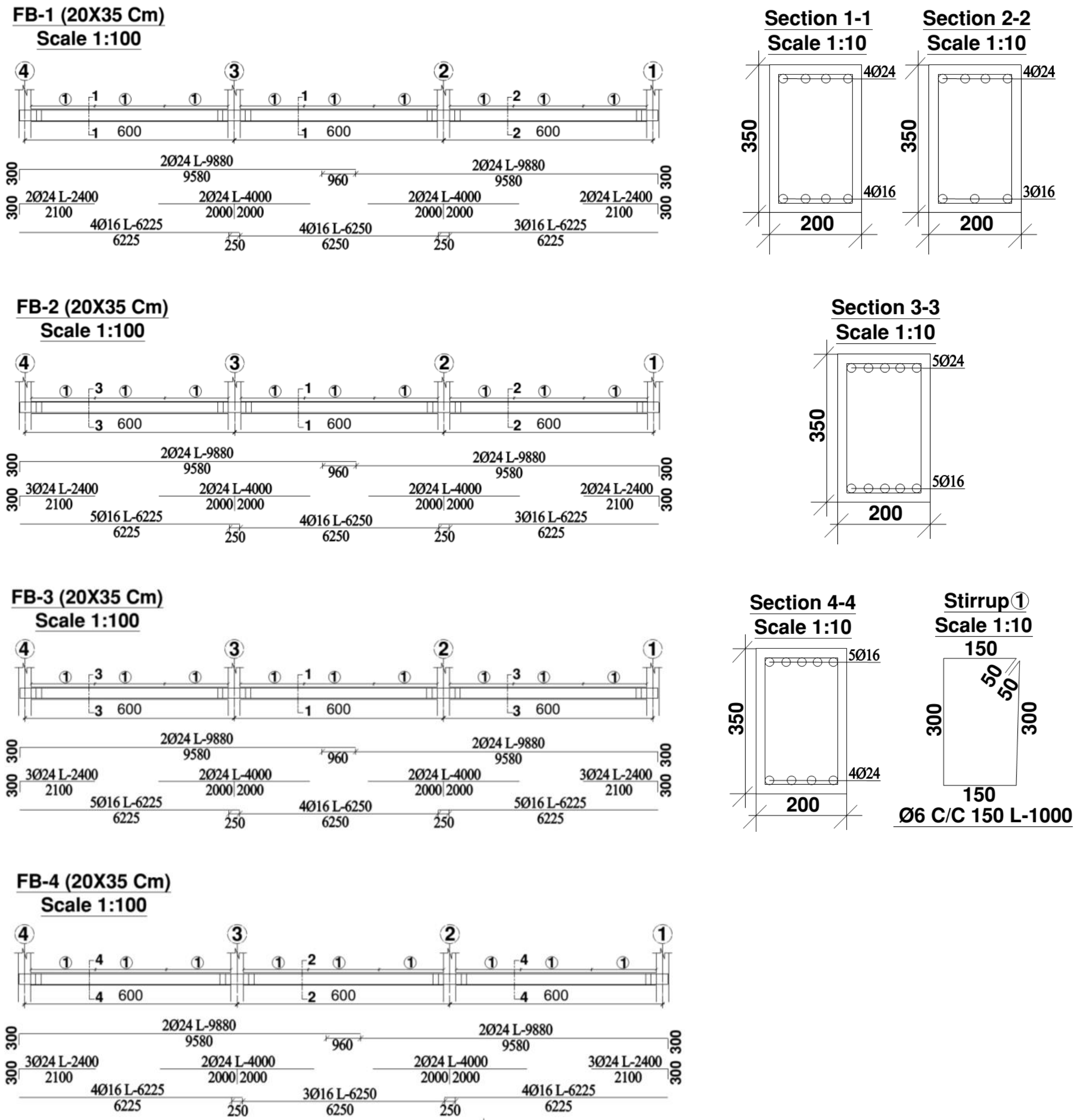


Figure D.16 Sample beam detailing for G+2 building with C-40 concrete

D.2.1.4 COLUMN DETAILING FOR G+2 BUILDING WITH C-40 CONCRETE

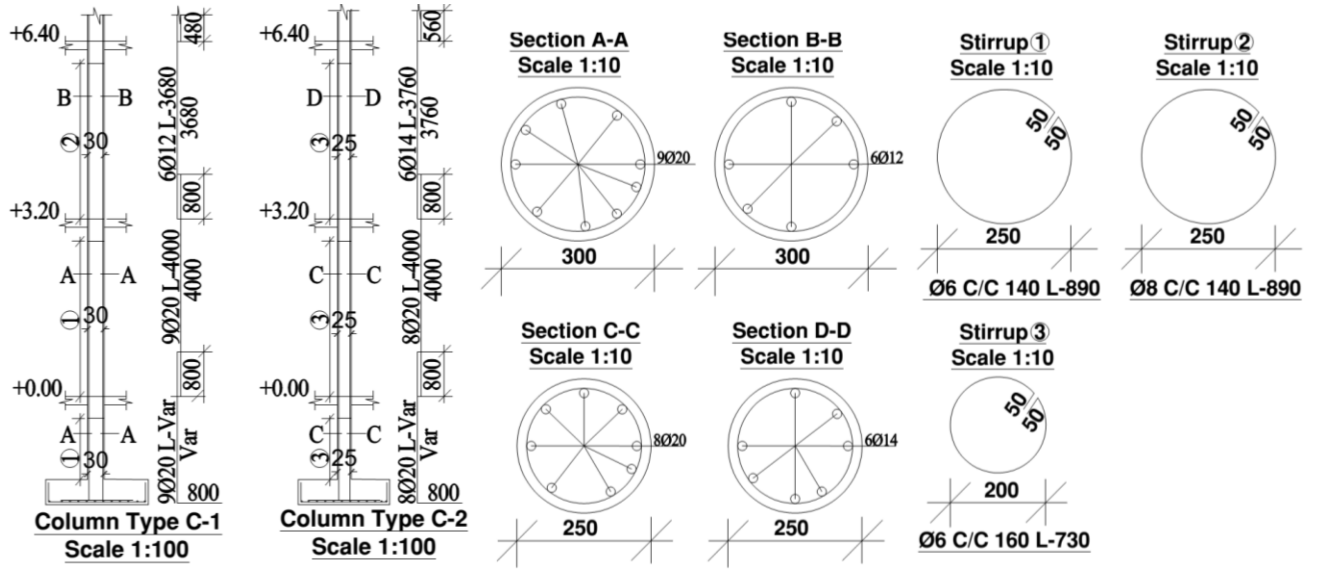


Figure D.17 Sample column detailing for G+2 building with C-40 concrete

D.2.1.5 FOUNDATION DETAILING FOR G+2 BUILDING WITH C-40 CONCRETE

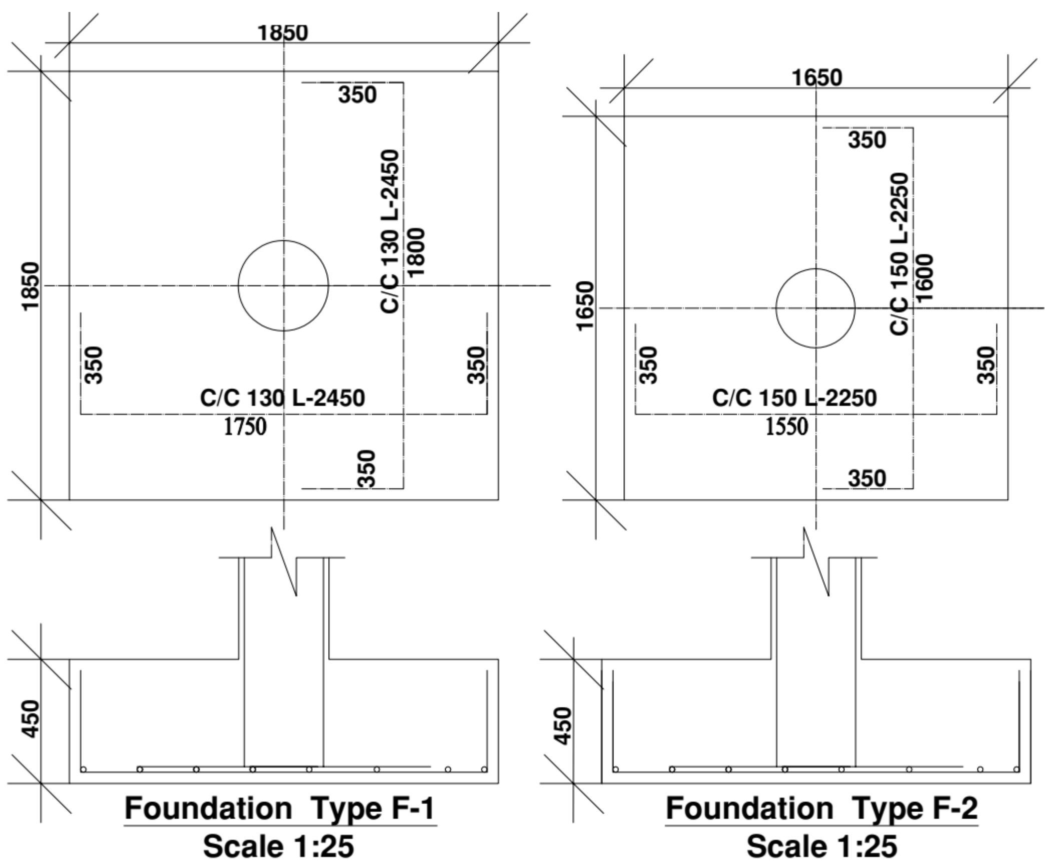


Figure D.18 Sample foundation detailing for G+2 building with C-40 concrete

D.2.2 STRUCTURAL DETAILING FOR G+7 BUILDING WITH C-40 CONCRETE

D.2.2.1 SLAB DETAILING FOR G+7 BUILDING WITH C-40 CONCRETE

Sample slab detailing for G+7 building is the same as sample slab detailing for G+2 building.

D.2.2.2 STAIRCASE DETAILING FOR G+7 BUILDING WITH C-40 CONCRETE

Sample staircase detailing for G+7 building is the same as sample staircase detailing for G+2 building.

D.2.2.3 BEAM DETAILING FOR G+7 BUILDING WITH C-40 CONCRETE

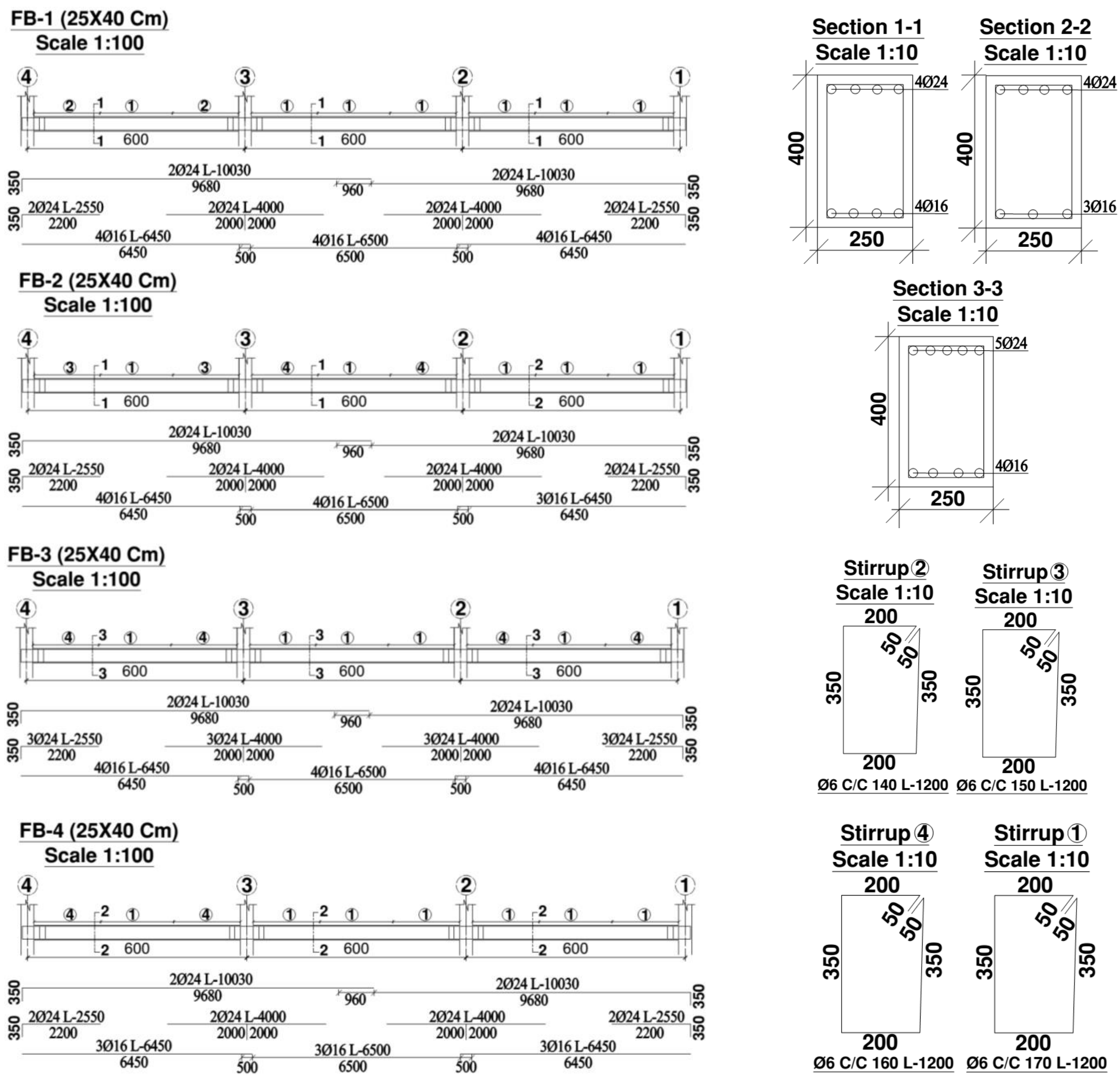


Figure D.19 Sample beam detailing for G+7 building with C-40 concrete

D.2.2.4 COLUMN DETAILING FOR G+7 BUILDING WITH C-40 CONCRETE

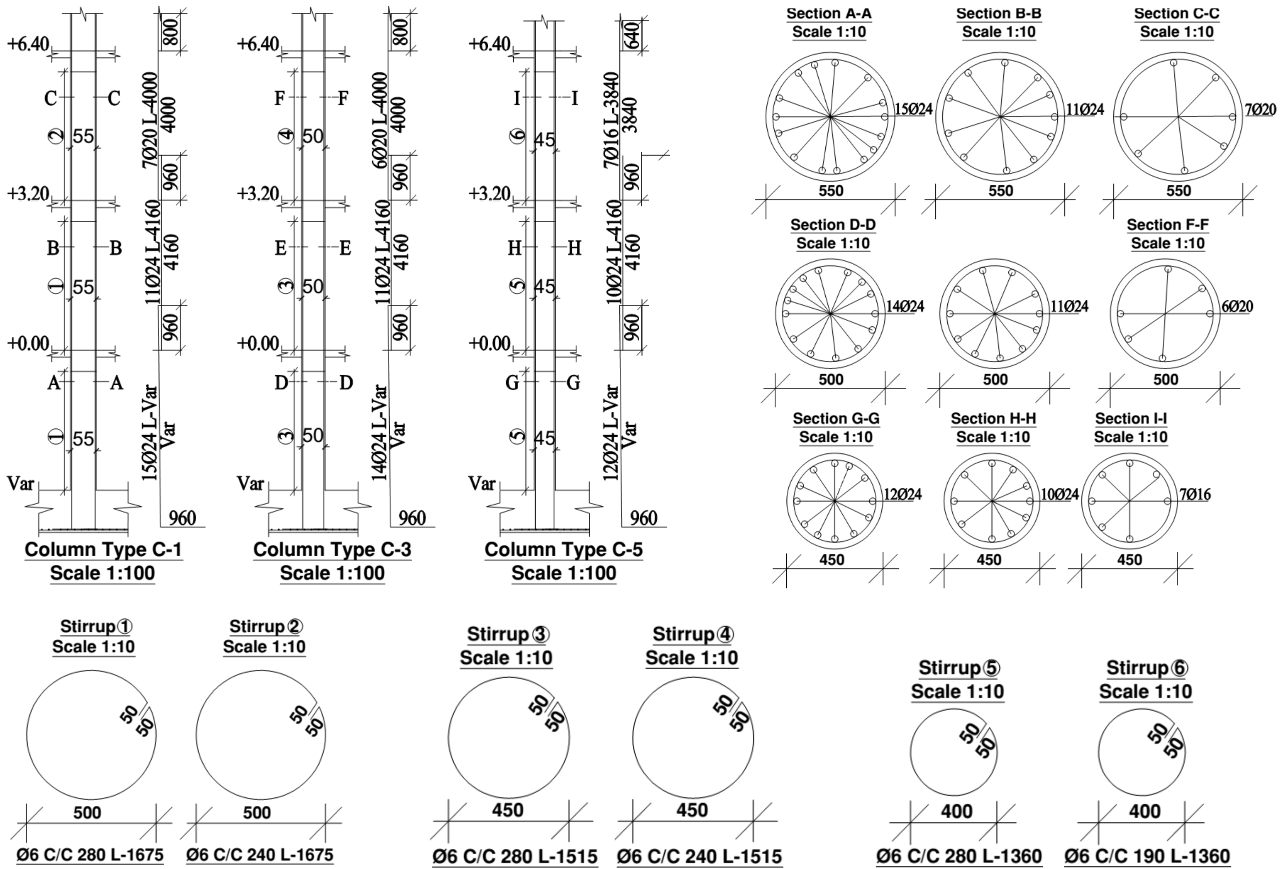


Figure D.20 Sample column detailing for G+7 building with C-40 concrete

D.2.2.5 FOUNDATION DETAILING FOR G+7 BUILDING WITH C-40 CONCRETE

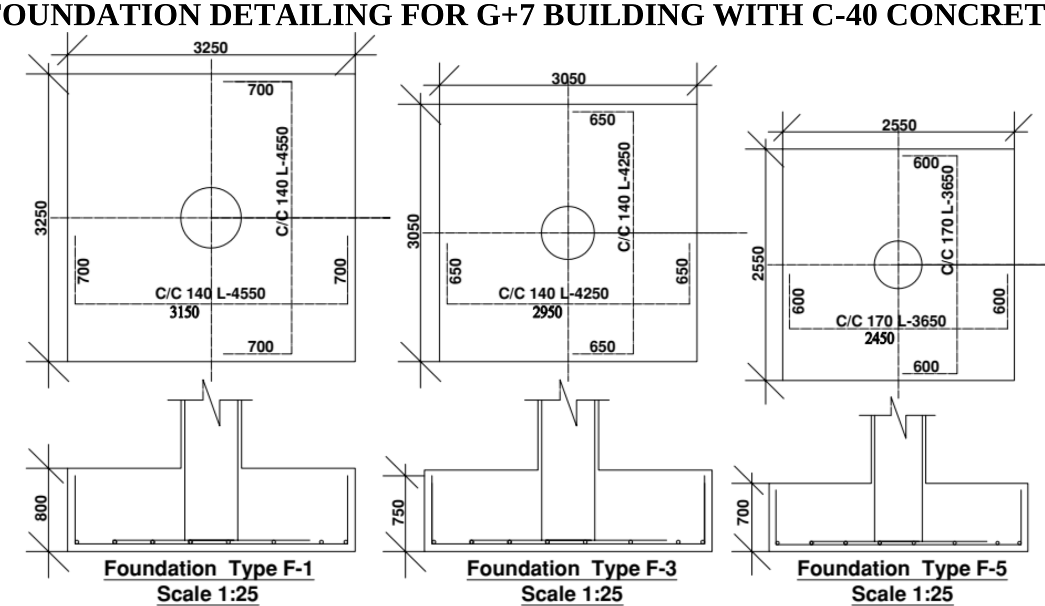


Figure D.21 Sample foundation detailing for G+7 building with C-40 concrete

D.2.3 STRUCTURAL DETAILING FOR G+12 BUILDING WITH C-40 CONCRETE

D.2.3.1 SLAB DETAILING FOR G+12 BUILDING WITH C-40 CONCRETE

Sample slab detailing for G+12 building is the same as sample slab detailing for G+2 building.

D.2.3.2 STAIRCASE DETAILING FOR G+12 BUILDING WITH C-40 CONCRETE

Sample staircase detailing for G+12 building is the same as sample staircase detailing for G+2 building.

D.2.3.3 BEAM DETAILING FOR G+12 BUILDING WITH C-40 CONCRETE

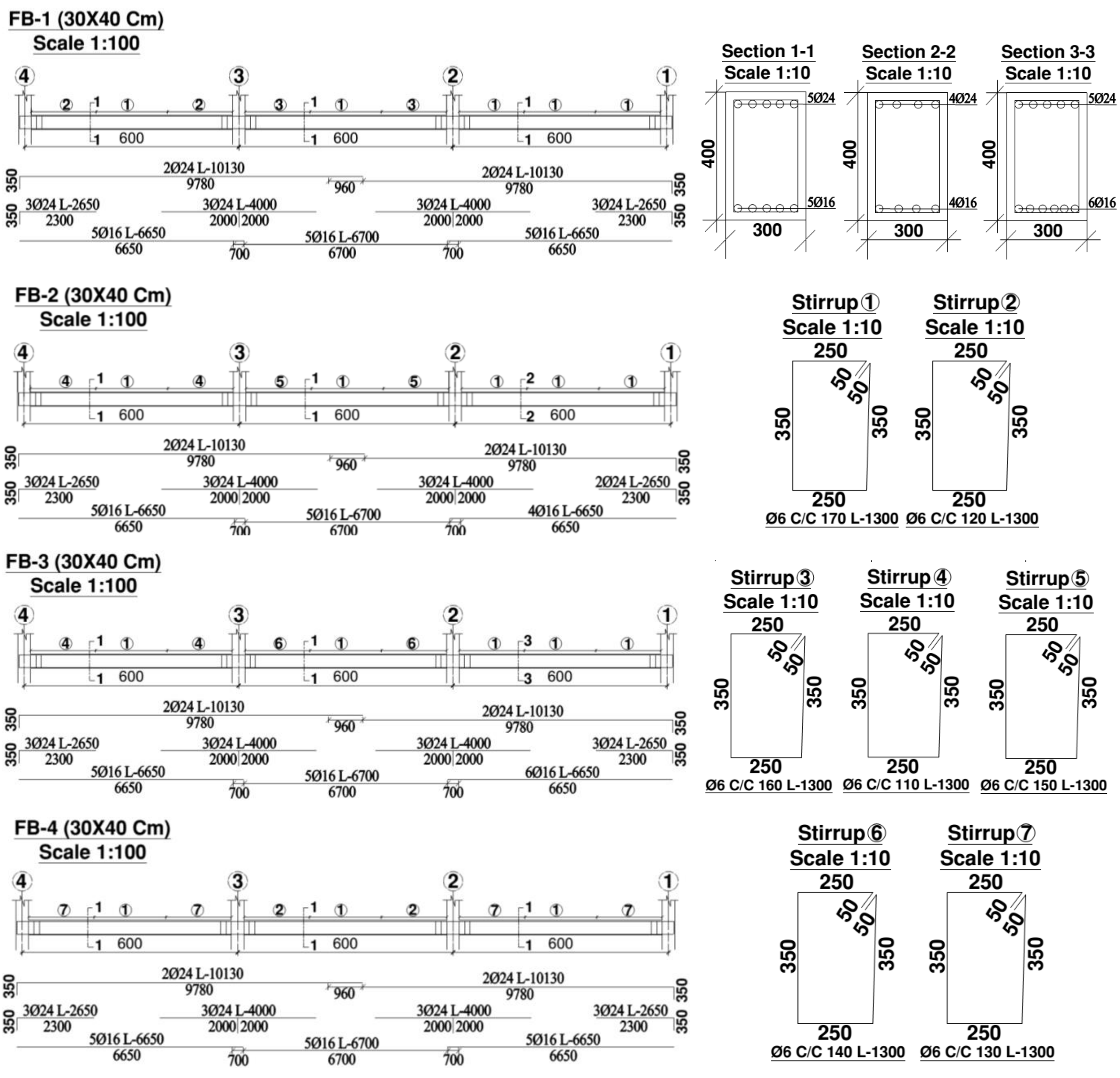


Figure D.22 Sample beam detailing for G+12 building with C-40 concrete

D.2.3.4 COLUMN DETAILING FOR G+12 BUILDING WITH C-40 CONCRETE

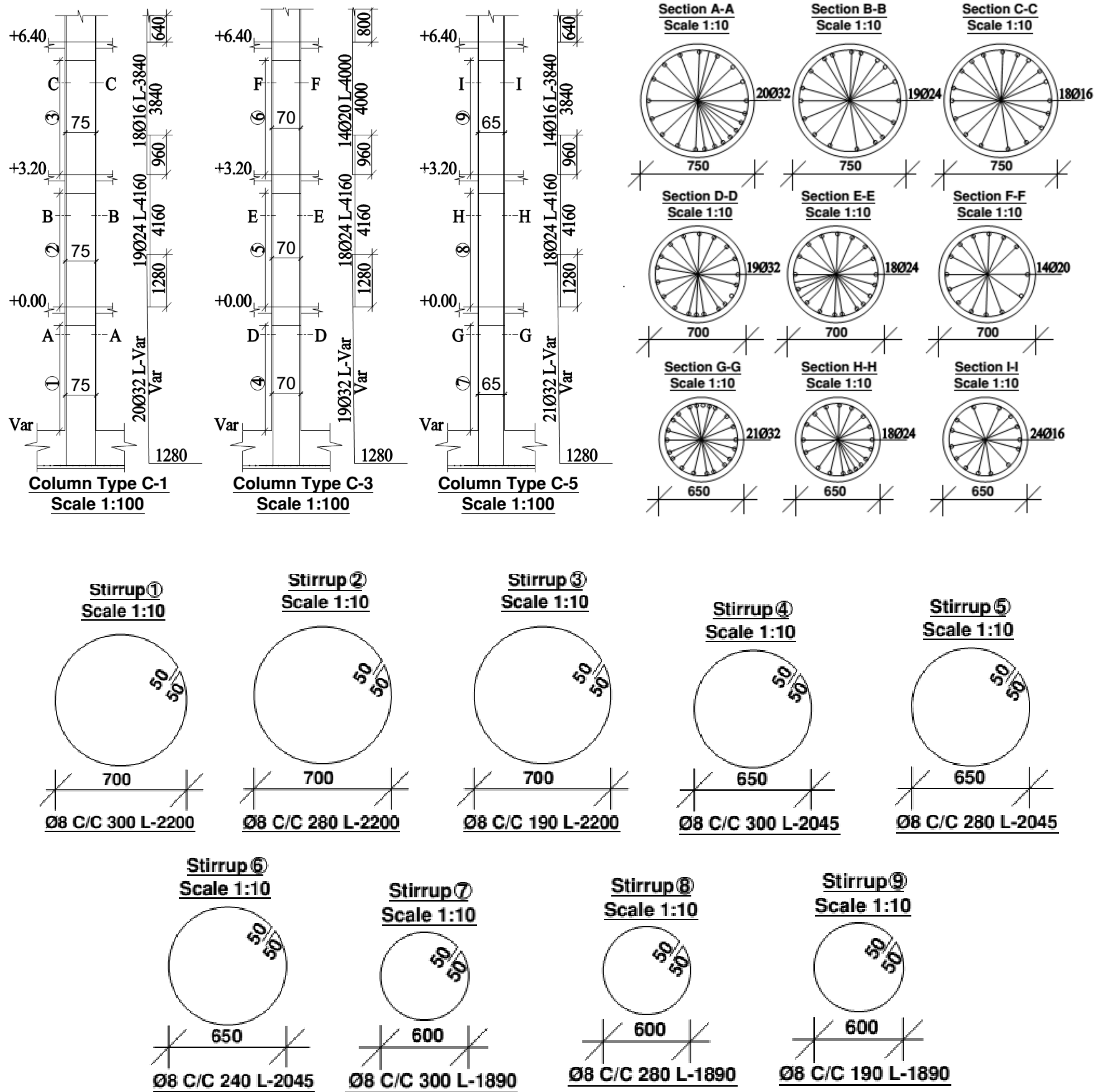


Figure D.23 Sample column detailing for G+12 building with C-40 concrete

D.2.3.5 FOUNDATION DETAILING FOR G+12 BUILDING WITH C-40 CONCRETE

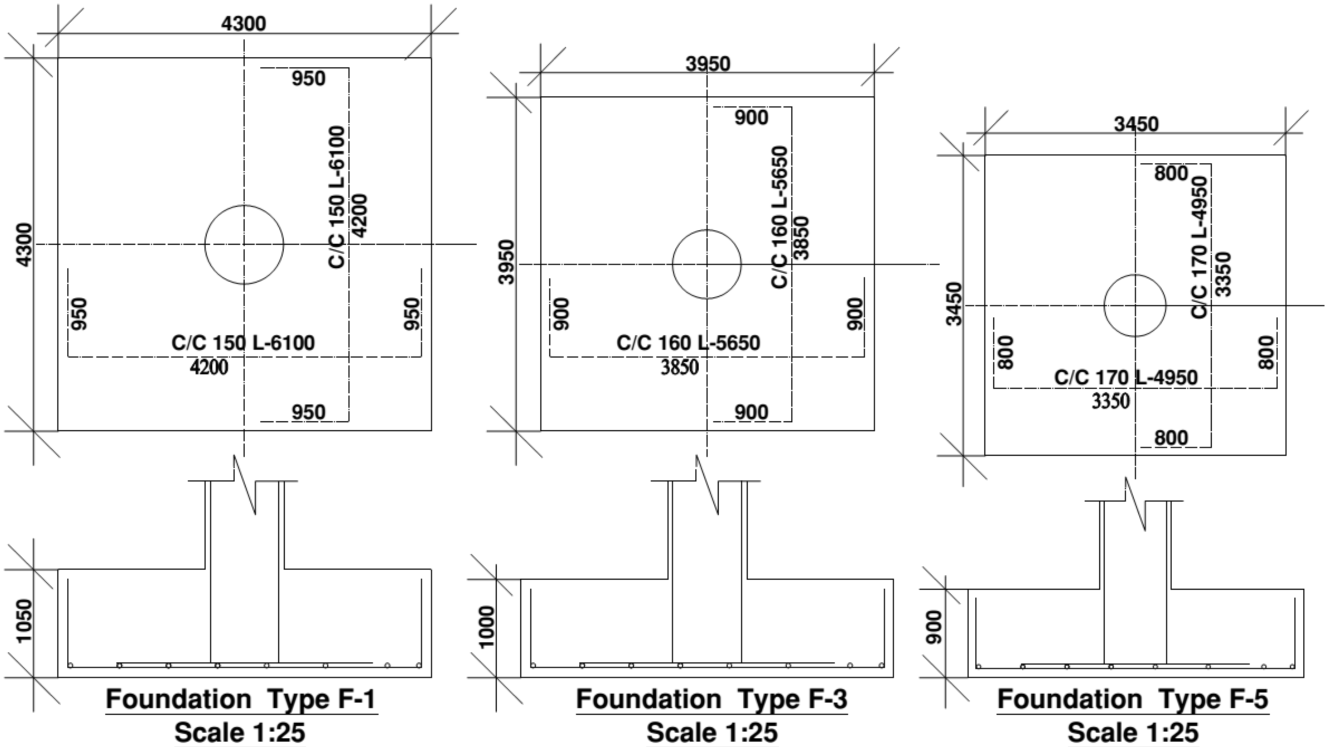


Figure D.24 Sample foundation detailing for G+12 building with C-40 concrete

APPENDIX E – DIRECT COST

E.1 MATERIAL COST

Table E.1 Material Cost

Item No.	Description	Unit	Average price
1	Selected material	m^3	180
2	Cement (PPC Grade 32.5 N)-Dangote	qtl	263
3	Cement (OPC Grade 42.5 N)-Dangote	qtl	264
4	Sand (Hauling distance greater than 5m)	m^3	550
5	Aggregate(02)-(at crasher site)	m^3	560
6	Water	m^3	7
7	Dia.6mm plain rebar	kg	65
8	Dia.8mm deformed rebar	kg	50.63
9	Dia.10mm deformed rebar	kg	50.2
10	Dia.12mm deformed rebar	kg	46.3
11	Dia.14mm deformed rebar	kg	46.85
12	Dia.16mm deformed rebar	kg	46.1
13	Dia.20mm deformed rebar	kg	46.47
14	Dia.24mm deformed rebar	kg	43.1
15	Dia.32mm deformed rebar	kg	38.86
16	Wooden formwork (Plywood)	Pcs (1.22x2.44m)	1100
17	Steel circular formwork	m^2	1000
18	Eucalyptus wood dia.12cm	ml	20
19	Eucalyptus wood dia.10cm	ml	19.5
20	Eucalyptus wood dia.8cm	ml	9.5
21	4*5cm Zigba purlin	ml	16.75
22	Typing wire	kg	55
23	1.5mm black annealed wire	ml	55
24	Nail	ml	60
25	Plastic paint	lit	83.33
26	Gypsum	kg	10
27	Admixture (Plasticizer)	lit	61
28	Fuel (Gas oil, Nfta)	lit	16.68
29	Stucco	kg	70
30	Brush 140 x 40mm (Used for 500m2)	pcs/m2	50
31	Sand paper	pcs	15
32	Animal or vinavil glue	kg	80

E.2 LABOR COST AND EQUIPMENT COST

Table E.2 Labor and equipment cost

Item. No	Description	Price per day	Item. No	Description	Price per day
1	Forman	400	9	Operator	250.00
2	Gange Chief	150	10	Mixer Operator	180.00
3	Daily Laborer	120	11	Driver	150
4	Chiseler	150	12	Excavator (wheel)	8800
5	Carpenter	350	13	Dump Truck (10-20m3)	2640
6	Mason	350	14	Mixer (350 lit)	680
2	Plasterer	350	15	Vibrator	200
3	Tiller	350	16	Bar cutter	60
4	Bar bender	250	17	Grinder	400
5	As. Carpenter	200	18	Hand tools	8
6	Helper	150	19	Form work for 1m2 (Monthly rate)	50.00
7	Painter	250	20	Formwork panel (Daily rent = 6 birr)	8.00
8	Welder	250	21	Hand Roller	300.00

APPENDIX F - UNIT RATE ANALYSIS

Table F.1 Sample unit rate analysis for pit excavation

TYPE OF WORK: **EXCAVATION AND EARTHWORK** LABOUR HOURLY OUTPUT: 125.00 m^3/hr
WORK ITEM: **1.A.1.1 Pit excvation up to 1.5m depth** EQUIPEMENT: 125.00 m3/hr
TOTAL QANTITY OF WORK ITEM: 1 m^3 RESULT : **115.89 Birr/m^3**

Item .No	Material Cost (1:01)					Labour Cost (1:02)					Equipment Cost (1:03)			
	Type of Material	Unit	Qty	Rate	Cost per Unit	Labour by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
1	Fuel (Nafta)	Lit	5	16.68	83.4	Foreman	1	1/4	50	12.50	Hand tools	1	1	1.00
						Helper	1	1	18.75	18.75	Excavator	1	1100	1,100.00
						Operator	1	1	31.25	31.25				
		Total (1:01)			83.40	**Total (1:02)**				62.50	**Total (1:03)**			1,101.00

A= Materials Unit Cost 83.40 Birr/m^2 B= Manpower Unit Cost 0.50 Birr/m^2 C= Equipment Unit Cos 8.81 Birr/m^2

Total of (1:02) 62.5 / Hourly Output 125.00 Total of (1:03) 1,101.00 / Hourly output: 125.00

Direct Cost of Work Item = A+B+C: 92.71 Birr/m^3
Over head cost : 15% 13.91 Birr/m^3
Profit : 10% 9.27 Birr/m^3
Total Unit Cost : 115.89 Birr/m^3

Table F.2 Sample unit rate analysis for backfill

TYPE OF WORK: **EXCAVATION AND EARTHWORK** LABOUR HOURLY OUTPUT: 2 m^3/hr
WORK ITEM: **1.A.1.3 and 1.A.1.4 Backfil** EQUIPEMENT: 2 m^3/hr
TOTAL QANTITY OF WORK ITEM: 1 m^3 RESULT : **368.06 Birr/m^3**

Item .No	Material Cost (1:01)					Labour Cost (1:02)					Equipment Cost (1:03)			
	Type of Material	Unit	Qty *	Rate	Cost per Unit	Labour by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
1	Selected material	m^3	1.250	180	225.00	Foreman	1	1/4	50	12.50	Hand Tools	1	1	1.00
2	Fuel (Benzin)	Lit	0.75	18.6	13.95	DL	4	1	15	60.00	Hand Roller	1	37.5	37.50
		Total (1:01)			238.95	**Total (1:02)**				72.50	**Total (1:03)**			38.50

A= Materials Unit Cost 238.95 Birr/m^3 B= Manpower Unit Cost 36.25 Birr/m^3 C= Equipment Unit Cost 19.25 Birr/m^3

Total of (1:02) 72.5 / Hourly Output 2.00 Total of (1:03) 38.5 / Hourly output: 2.00

Direct Cost of Work Item = A+B+C: 294.45 Birr/m^3
Over head cost : 15% 44.17 Birr/m^3
Profit : 10% 29.45
Total Unit Cost : 368.06 Birr/m^3

Table F.3 Unit rate analysis for cart way

TYPE OF WORK: **EXCAVATION AND EARTHWORK** LABOUR HOURLY OUTPUT: 37.5 m^3/hr

WORK ITEM: **1.A.1.5 Cart away** EQUIPEMENT: 37.5 m^3/hr

TOTAL QANTITY OF WORK ITEM: 1 m^3 RESULT : **141.00 Birr/m^3**

Item .No	Material Cost (1:01)					Labour Cost (1:02)					Equipment Cost (1:03)			
	Type of Material	Unit	Qty *	Rate	Cost per Unit	Labour by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
1	Fuel (Nafta) for D.T	Lit	2.5	16.68	41.7	Foreman	1	1/4	50	12.50	Hand tools	1	1	1.00
2	Fuel (Nafta) for Exc.	Lit	1.875	16.68	31.275	Helper	1	1	18.75	18.75	Excavator	1	1100	1,100.00
						Operator	1	1	31.25	31.25	Dump Truck	1	330	330.00
		Total (1:01)			72.98	**Total (1:02)**				62.50	**Total (1:03)**			1,431.00

A= Materials Unit Cost 72.98 Birr/m^3 B= Manpower Unit Cost 1.67 Birr/m^3 C= Equipment Unit Cost 38.16 Birr/m^3

Total of (1:02) 62.5 / Hourly Output 37.50 Total of (1:03) 1431 / Hourly output: 37.50

Direct Cost of Work Item = A+B+C:		112.80	Birr/m^3
Over head cost :	15%	16.92	Birr/m^3
Profit :	10%	11.28	Birr/m^3
Total Unit Cost :		**141.00**	Birr/m^3

Table F.4 Unit rate analysis for lean concrete

TYPE OF WORK: **CONCRETE WORK** LABOUR HOURLY OUTPUT: 45 m^2/hr

WORK ITEM: **1.A.2.1 50mm Lean concrete (Machine mix) - C-5** EQUIPEMENT: 45 m^2/hr

TOTAL QANTITY OF WORK ITEM: 1 m^2 RESULT : **93.13 Birr/m^2**

Item .No	Material Cost (1:01)					Labour Cost (1:02)					Equipment Cost (1:03)			
	Type of Material	Unit	Qty	Rate	Cost per Unit	Labour by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
1	Cement	kg	7.500	2.63	19.73	Foreman	1	1/4	50	12.5	Hand tools	1	1.00	1.00
2	Sand	m^3	0.021	550.00	11.55	DL	45	1	15	675	Mixer	1	85.00	85.00
3	Aggregate	m^3	0.042	560.00	23.52	Mason	2	1	43.75	87.5	Vibrator	1	25.00	25.00
4	Water	m^3	0.003	7.00	0.02									
		Total (1:01)			54.82	**Total (1:02)**				775.00	**Total (1:03)**			111.00

A= Materials Unit Cost 54.82 Birr/m^2 B= Manpower Unit Cost 17.22 Birr/m^2 C= Equipment Unit Cost 2.47 Birr/m^2

Total of (1:02) 775 / Hourly Output 45.00 Total of (1:03) 111 / Hourly output: 45.00

Direct Cost of Work Item = A+B+C:		74.50	Birr/m^2
Over head cost :	15%	11.18	Birr/m^2
Profit :	10%	7.45	Birr/m^3
Total Unit Cost :		**93.13**	Birr/m^2

Table F.5 Sample Unit rate analysis for reinforced concrete work with C-25 concrete

TYPE OF WORK: **CONCRETE WORK** LABOUR HOURLY OUTPUT: 2.25 m^3/hr

WORK ITEM: **1.A.2.2 &1.B.1.1 Reinforced concrete (Machine mix) - C-25 for footing** EQUIPEMENT: 2.25 m^3/hr

TOTAL QANTITY OF WORK ITEM: 1 m^3 RESULT : **2,731.99 Birr/m^3**

Item .No	**Material Cost (1:01)**					**Labour Cost (1:02)**					**Equipment Cost (1:03)**			
	Type of Material	Unit	Qty	Rate	Cost per Unit	Labour by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
1	Cement	kg	360.000	2.63	1,183.50	Foreman	1	1/4	50.00	12.50	Hand tools	1	1.00	1.00
2	Sand	m^3	0.42	550	233.46	DL	45	1	15.00	675.00	Mixer	1	85.00	85.00
3	Aggregate	m^3	0.67	560	373.45	mason	2	1	43.75	87.50	Vibrator	1	25.00	25.00
4	Water	m^3	0.2	7	1.40									
		Total (1:01)			1,791.81	**Total (1:02)**				775.00	**Total (1:03)**			111.00

A= Materials Unit Cost 1,791.81 Birr/m^3 B= Manpower Unit Cost 344.44 Birr/m^3 C= Equipment Unit Cost 49.33 Birr/m^3

$\frac{\text{Total of (1:02)}}{\text{Hourly Output}}$ $\frac{775}{2.25}$ $\frac{\text{Total of (1:03)}}{\text{Hourly output:}}$ $\frac{111}{2.25}$

Direct Cost of Work Item = A+B+C:		2,185.59	Birr/m^3
Over head cost :	15%	327.84	Birr/m^3
Profit :	10%	218.56	Birr/m^3
Total Unit Cost :		**2,731.99**	Birr/m^3

Table F.6 Sample Unit rate analysis for reinforced concrete work with C-40 concrete

TYPE OF WORK: **CONCRETE WORK** LABOUR HOURLY OUTPUT: 2.25 m^3/hr

WORK ITEM: **1.A.2.2 & 1.B.1.1 Reinforced concrete (Machine mix) - C-40 for footing** EQUIPEMENT: 2.25 m^3/hr

TOTAL QANTITY OF WORK ITEM: 1 m^3 RESULT : **3,280.18 Birr/m^3**

Item .No	**Material Cost (1:01)**					**Labour Cost (1:02)**					**Equipment Cost (1:03)**			
	Type of Material	Unit	Qty *	Rate	Cost per Unit	Labour by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
1	Cement	kg	360	2.63	1,183.50	Foreman	1	1/4	50.00	12.50	Hand tools	1	1.00	1.00
2	Sand	m^3	0.42	550	233.46	DL	45	1	15.00	675.00	Mixer	1	85.00	85.00
3	Aggregate	m^3	0.67	560	373.45	Mason	2	1	43.75	87.50	Vibrator	1	25.00	25.00
4	Water	m^3	0.108	7	0.76									
5	Addmixture	Lit	7.2	61	439.20									
		Total (1:01)			2,230.37	**Total (1:02)**				775.00	**Total (1:03)**			111.00

A= Materials Unit Cost 2,230.37 Birr/m^3 B= Manpower Unit Cost 344.44 Birr/m^3 C= Equipment Unit Cost 49.33 Birr/m^3

$\frac{\text{Total of (1:02)}}{\text{Hourly Output}}$ $\frac{775}{2.25}$ $\frac{\text{Total of (1:03)}}{\text{Hourly output:}}$ $\frac{111}{2.25}$

Direct Cost of Work Item = A+B+C:		2,624.14	Birr/m^3
Overhead cost :	15%	393.62	Birr/m^3
Profit :	10%	262.41	Birr/m^3
Total Unit Cost :		**3,280.18**	Birr/m^3

Table F.7 Sample unit rate analysis for reinforcement work

TYPE OF WORK: **REINFORCEMENT WORKS** ABOUR HOURLY OUTPUT: 10 kg/hr
WORK ITEM: **1.A.2.4 & 1.B.1.3 Diameter 16mm Deformed bar** EQUIPEMENT: 10 kg/hr
TOTAL QANTITY OF WORK ITEM: 1 kg RESULT : **72.16 Birr/kg**

Item .No	**Material Cost (1:01)**					**Labour Cost (1:02)**					**Equipment Cost (1:03)**			
	Type of Material	Unit	Qty	Rate	Cost per Unit	Labour by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
1	Dia 16mm plain bar	kg	1.05	46.10	48.41	Forman	1	1/4	50	12.50	Hand tools	1	1	1.00
2	Wire	kg	0.02	55	1.10	Bar bender	1	1	31.25	31.25	Bar cutter	1	7.5	7.50
						DL	2	1	15	30.00				
		Total (1:01)			49.51	**Total (1:02)**				73.75	**Total (1:03)**			8.50

A= Materials Unit Cost 49.51 Birr/kg B= Manpower Unit Cost 7.38 Birr/kg C= Equipment Unit Cost 0.85 Birr/kg

Total of (1:02) / Hourly Output = 73.75 / 10.00 Total of (1:03) / Hourly output: = 8.5 / 10.00

Direct Cost of Work Item = A+B+C: 57.73 Birr/kg
Over head cost : 15% 8.66 Birr/kg
Profit : 10% 5.77 Birr/kg
Total Unit Cost : 72.16 Birr/kg

Table F.8 Sample unit rate analysis for formwork

TYPE OF WORK: **FORMWORK** LABOUR HOURLY OUTPUT: 1.25 m^2/hr
WORK ITEM: **1.A.2.3 & 1.B.1.2 Formwork for footing, slab, beam & staircase** EQUIPEMENT: 1.25 m^2/hr
TOTAL QANTITY OF WORK ITEM: 1 m^2 RESULT : **228.24 Birr/m^2**

Item .No	**Material Cost (1:01)**					**Labour Cost (1:02)**					**Equipment Cost (1:03)**			
	Type of Material	Unit	Qty	Rate	Cost per Unit	Labour by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
1	Wooden formwork (Plawod)	m^2	1.05	61.11	64.17	Foreman	1	1/4	50	12.50	Hand tools	1	1	1.00
2	Eucalyptus wood dia.12cm	ml	1.05	6.67	7.00	DL	1	1	15	15.00				
3	Eucalyptus wood dia.10cm	ml	4.00	6.5	26.00	Carpenter	1	1	43.75	43.75				
4	Nail	kg	0.3	60	18.00	A.Carpente	1	1	25	25.00				
5	Typing wire	kg	0.1	55	5.50									
		Total (1:01)			120.67	**Total (1:02)**				96.25	**Total (1:03)**			1.00

A= Materials Unit Cost 120.67 Birr/m^2 B= Manpower Unit Cost 77.00 Birr/m^2 C= Equipment Unit Co 0.80 Birr/m^2

Total of (1:02) / Hourly Output = 96.25 / 1.25 Total of (1:03) / Hourly output: = 1.00 / 1.25

Direct Cost of Work Item = A+B+C: 198.47 Birr/m^2
Over head t cost : 15% 29.77 Birr/m^2
Profit : 10% 19.85 Birr/m^2
Total Unit Cost : 228.24 Birr/m^2

Table F.9 Sample unit rate analysis for plastering

TYPE OF WORK: **PLASTERING** LABOUR HOURLY OUTPUT: 1.25 m^2/hr

WORK ITEM: **1.B.2.1 Two coats of plastering** EQUIPEMENT: 1.25 m2/hr

TOTAL QANTITY OF WORK ITEM: 1 m^2 RESULT : **161.26 Birr/m^2**

Item .No	Material Cost (1:01)					Labour Cost (1:02)					Equipment Cost (1:03)			
	Type of Material	Unit	Qty	Rate	Cost per Unit	Labour by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
1	Cement	kg	21.06	2.63	55.39	Foreman	1	1/4	50	12.50	Hand tools	1	1	1.00
2	Sand	m^3	0.025	550	13.75	DL	2	1	15	30.00				
3	Water	Lit	9.48	0.007	0.07	Plasterer	1	1	43.75	43.75				
		Total (1:01)			69.20	**Total (1:02)**				73.75	**Total (1:03)**			1.00

A= Materials Unit Cost 69.20 Birr/m^2 B= Manpower Unit Cost 59.00 Birr/m^2 C= Equipment Unit Co: 0.80 Birr/m^2

$\frac{\text{Total of (1:02)}}{\text{Hourly Output}}$ $\frac{73.75}{1.25}$ $\frac{\text{Total of (1:03)}}{\text{Hourly output:}}$ $\frac{1.00}{1.25}$

Direct Cost of Work Item = A+B+C: 129.00 Birr/m^2

Over head cost : 15% 19.35 Birr/m^2

Profit : 10% 12.90 Birr/m^3

Total Unit Cost : **161.26** Birr/m^2

Table F.10 Sample unit rate analysis for painting

TYPE OF WORK: **PAINTING** LABOUR HOURLY OUTPUT: 3.75 m^2/hr

WORK ITEM: **1.B.3.1 Three coats of plastic paint** EQUIPEMENT: 3.75 m2/hr

TOTAL QANTITY OF WORK ITEM: 1 m^2 RESULT : **53.31 Birr/m^2**

Item .No	Material Cost (1:01)					Labour Cost (1:02)					Equipment Cost (1:03)			
	Type of Material	Unit	Qty	Rate	Cost per Unit	Labour by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
1	3 coats of pl	lit	0.3	83.33	25.00	Foreman	1	1/4	50	12.50	Hand tools	1	1	1.00
2	Stucco	kg	0.05	70	3.50	DL	1	1	15	15.00				
3	Brush	pcs	0.002	50	0.10	Painter	1	1	31.25	31.25				
4	Sand paper	pcs	0.01	15	0.15									
5	Gypsum	Kg	0.03	10	0.30									
6	Animal or vir	Kg	0.0125	80	1.00									
		Total (1:01)			30.05	**Total (1:02)**				46.25	**Total (1:03)**			1.00

A= Materials Unit Cost 30.05 Birr/m^2 B= Manpower Unit Cost 12.33 Birr/m^2 C= Equipment Unit Co: 0.27 Birr/m^2

$\frac{\text{Total of (1:02)}}{\text{Hourly Output}}$ $\frac{46.25}{3.75}$ $\frac{\text{Total of (1:03)}}{\text{Hourly output:}}$ $\frac{1.00}{3.75}$

Direct Cost of Work Item = A+B+C: 42.65 Birr/m^2

Over head cost : 15% 6.40 Birr/m^2

Profit : 10% 4.27 Birr/m^3

Total Unit Cost : **53.31** Birr/m^2

APPENDIX G – BILL OF QUANTITY

Table G.1 Priced bill of quantity for G+2 building

Item No	DESCRIPTION	Unit	Cost with C-25 Concrete			Cost with C-40 Concrete		
			Qty	Rate	Amount	Qty	Rate	Amount
	1.A. SUBSTRUCTURE WORK **1.A.1 EXCAVATION & EARTH WORKS**							
1.A.1.1	Pit excavation for isolated footing to the depth below 1500mm from reduced level. Price shall be include 250mm working space in all sides.	m^3	336.79	115.89	39,029.14	301.13	115.89	34,895.87
1.A.1.2	Ditto item 1.A.1.1. but depth below 1500-3000mm from reduced level. Price shall be include 250mm working space in all sides.	m^3	-	135.14	-	-	135.14	-
1.A.1.3	Back fill around footings with non-expansive granular selected borrowed material and compact in layers of 200mm thick until compaction attaining 98% dry density.	m^3	36.09	368.06	13,283.38	30.00	368.06	11,041.88
1.A.1.4	Back fill around foundation coumn with non-expansive granular selected borrowed material and compact in layers of 200mm thick until compaction attaining 98% dry density.	m^3	237.52	368.06	87,421.42	225.57	368.06	83,023.48
1.A.1.5	Loaded and cart away surplus excavated material to a distance not exceeding 5km from the site.	m^3	336.79	141.00	47,488.37	301.13	141.00	42,459.25
	Total Carried to Summary……………………………….				**187,222.31**			**171,420.48**
	1.A.2 CONCRETE WORK							
1.A.2.1	50mm thick lean concrete in concrete class C-5, 150kgs of cement /m^3 of concrete							
	a. Under footings	m^2	99.66	93.13	9,281.45	92.18	93.13	8,584.36
	b.Under grade beam	m^2	73.01	93.13	6,799.53	59.28	93.13	5,520.77
1.A.2.2	Reinforced Concrete of class C-25 (concrete without concrete grade enhancer admixture) and C-40 (concrete with concrete grade enhancer admixture of 1.5% by weight of cement) with a minimum cement content of 450kg /m^3 and filled into form work and vibrated around steel reinforcement. (Form work and Rebar measured separately.)							
	a. Footing	m^3	53.08	2,731.99	145,011.07	41.48	3,280.18	136,057.80
	b.Foundation column	m^3	5.12	3,258.10	16,688.38	2.59	3,806.29	9,848.99
	c. Grade beam	m^3	29.26	2,890.48	84,580.58	20.77	3,438.67	71,422.99
1.A.2.3	Provide, cut and fix in position sawn structural wood or steel formwork which ever is appropriate.							
	a. Footing	m^2	116.04	228.24	26,484.58	95.06	228.24	21,695.04
	b.Foundation column	m^2	49.49	275.20	13,618.26	35.09	275.20	9,657.13
	c. Grade beam	m^2	233.31	228.24	53,249.86	206.87	228.24	47,214.43
1.A.2.4	Steel reinforcement according to structural drawings. Price includins bar cutting, bending, tying wires & placing in position.							
	a. Footing							
	Diamerer 6mm plain bar	kg	-	96.97	-	-	96.97	-
	Diamerer 8mm deformed bar	kg	-	78.11	-	-	78.11	-
	Diamerer 10mm deformed bar	kg	-	77.54	-	-	77.54	-
	Diamerer 12mm deformed bar	kg	-	72.43	-	-	72.43	-
	Diamerer 14mm deformed bar	kg	-	73.15	-	-	73.15	-
	Diamerer 16mm deformed bar	kg	3,057.56	72.16	220,641.29	2,887.07	72.16	208,337.87
	Diamerer 20mm deformed bar	kg	-	72.65	-	-	72.65	-
	Diamerer 24mm deformed bar	kg	-	68.23	-	-	68.23	-
	Diamerer 32mm deformed bar	kg	-	62.66	-	-	62.66	-
	b. Foundation column							
	Diamerer 6mm plain bar	kg	-	96.97	-	47.57	96.97	4,612.39
	Diamerer 8mm deformed bar	kg	99.27	78.11	7,753.52	-	78.11	-
	Diamerer 10mm deformed bar	kg	-	77.54	-	-	77.54	-
	Diamerer 12mm deformed bar	kg	-	72.43	-	-	72.43	-
	Diamerer 14mm deformed bar	kg	-	73.15	-	-	73.15	-
	Diamerer 16mm deformed bar	kg	-	72.16	-	-	72.16	-
	Diamerer 20mm deformed bar	kg	2,703.96	72.65	196,437.62	2,227.40	72.65	161,816.43
	Diamerer 24mm deformed bar	kg	-	68.23	-	-	68.23	-
	Diamerer 32mm deformed bar	kg	-	62.66	-	-	62.66	-
	Total Carried to Summary……………………..………………				**780,546.14**			**684,768.21**

Item No	DESCRIPTION	Unit	Cost with C-25 Concrete			Cost with C-40 Concrete		
			Qty	Rate	Amount	Qty	Rate	Amount
	1.B SUPER-STRUCTURE **1.B.1 CONCRETE WORK**							
1.B.1.1	Reinforced Concrete of class C-25 (concrete without concrete grade enhancer admixture) and C-40 (concrete with concrete grade enhancer admixture of 1.5% by weight of cement) with a minimum cement content of 450kg /m^3 and filled into form work and vibrated around steel reinforcement. (Form work and Rebar measured separately.)							
	a. Sample Elevation Column	m^3	22.52	3,258.10	73,359.47	10.47	3,806.29	39,865.94
	b. Sample Staircase	m^3	4.60	2,695.26	12,391.47	4.19	3,243.46	13,576.79
	c. Sample Floor Beam	m^3	18.64	2,890.48	53,871.28	11.99	3,438.67	41,222.81
	d. Sample Floor Slab	m^3	136.92	2,695.26	369,047.62	136.92	3,243.46	444,108.94
1.B.1.2	Provide, cut and fix in position sawn structural wood or steel formwork which ever is appropriate.							
	a. Sample Elevation Column	m^2	193.74	275.20	53,316.96	137.91	275.20	37,951.41
	b. Sample Staircase	m^2	28.12	228.24	6,418.02	27.57	228.24	6,292.76
	c. Sample Floor Beam	m^2	219.90	228.24	50,189.24	177.42	228.24	40,493.75
	d. Sample Floor Slab	m^2	927.04	228.24	211,585.09	927.04	228.24	211,585.09
1.B.1.3	Steel reinforcement according to structural drawings. Price includins bar cutting, bending, tying wires & placing in position.							
	a. Sample Elevation Column							
	Diamerer 6mm plain bar	kg	-	96.97	-	148.58	96.97	14,408.06
	Diamerer 8mm deformed bar	kg	324.46	78.11	25,343.22	132.77	78.11	10,370.71
	Diamerer 10mm deformed bar	kg	213.12	77.54	16,526.12	-	77.54	-
	Diamerer 12mm deformed bar	kg	-	72.43	-	352.93	72.43	25,560.72
	Diamerer 14mm deformed bar	kg	490.82	73.15	35,901.61	327.21	73.15	23,934.41
	Diamerer 16mm deformed bar	kg	654.70	72.16	47,245.12	-	72.16	-
	Diamerer 20mm deformed bar	kg	3,019.20	72.65	219,339.22	2,545.60	72.65	184,933.07
	Diamerer 24mm deformed bar	kg	-	68.23	-	-	68.23	-
	Diamerer 32mm deformed bar	kg	-	62.66	-	-	62.66	-
	b. Sample Floor Beam							
	Diamerer 6mm plain bar	kg	119.35	96.97	11,572.95	103.90	96.97	10,074.67
	Diamerer 8mm deformed bar	kg	24.63	78.11	1,923.58	-	78.11	-
	Diamerer 10mm deformed bar	kg	-	77.54	-	-	77.54	-
	Diamerer 12mm deformed bar	kg	-	72.43	-	-	72.43	-
	Diamerer 14mm deformed bar	kg	-	73.15	-	-	73.15	-
	Diamerer 16mm deformed bar	kg	509.91	72.16	36,796.33	472.30	72.16	34,082.18
	Diamerer 20mm deformed bar	kg	-	72.65	-	-	72.65	-
	Diamerer 24mm deformed bar	kg	980.99	68.23	66,928.14	967.85	68.23	66,031.50
	Diamerer 32mm deformed bar	kg	-	62.66	-	-	62.66	-
	c. Sample Floor Slab							
	Diamerer 6mm plain bar	kg	159.51	96.97	15,467.19	159.51	96.97	15,467.19
	Diamerer 8mm deformed bar	kg	2,841.13	78.11	221,915.21	2,819.96	78.11	220,261.82
	Diamerer 10mm deformed bar	kg	4,554.47	77.54	353,170.59	4,468.80	77.54	346,527.62
	Diamerer 12mm deformed bar	kg	-	72.43	-	-	72.43	-
	Diamerer 14mm deformed bar	kg	-	73.15	-	-	73.15	-
	Diamerer 16mm deformed bar	kg	-	72.16	-	-	72.16	-
	Diamerer 20mm deformed bar	kg	-	72.65	-	-	72.65	-
	Diamerer 24mm deformed bar	kg	-	68.23	-	-	68.23	-
	Diamerer 32mm deformed bar	kg	-	62.66	-	-	62.66	-
	d. Sample floor staircase							
	Diamerer 6mm plain bar	kg	-	96.97	-	-	96.97	-
	Diamerer 8mm deformed bar	kg	117.50	78.11	9,177.72	99.85	78.11	7,799.15
	Diamerer 10mm deformed bar	kg	91.32	77.54	7,080.99	91.32	77.54	7,080.99
	Diamerer 12mm deformed bar	kg	-	72.43	-	-	72.43	-
	Diamerer 14mm deformed bar	kg	169.26	73.15	12,380.96	169.26	73.15	12,380.96
	Diamerer 16mm deformed bar	kg	-	72.16	-	-	72.16	-
	Diamerer 20mm deformed bar	kg	-	72.65	-	-	72.65	-
	Diamerer 24mm deformed bar	kg	-	68.23	-	-	68.23	-
	Diamerer 32mm deformed bar	kg	-	62.66	-	-	62.66	-
	Total Carried to Summary…………………………………………				**1,910,948.12**			**1,814,010.52**
	1.B.2 FINISHING WORK							
1.B.2.1	Apply two coats of plastering in cement mortar (1:3) .Price shall include chiseling,pre-cleaning and preparation of the surface.							
	a. Sample Elevation Column	m^2	193.74	161.26	31,241.98	137.91	161.26	22,238.27
	b. Sample Floor Beam	m^2	219.90	161.26	35,460.01	177.42	161.26	28,609.89
	Total Carried to Summary…………………………………………				**66,701.99**			**50,848.16**
	1.B.3 PAINTING							-
1.B.3.1	Apply three coats of plastic emulsion paint. Price shall include pre - cleaning & preparation of the surface.							-
	a. Sample Elevation Column	m^2	193.74	53.31	10,328.90	137.91	53.31	7,352.18
	b. Sample Floor Beam	m^2	219.90	53.31	11,723.42	177.42	53.31	9,458.70
	Total Carried to Summary…………………………………………				**22,052.32**			**16,810.89**

Table G.2 Priced bill of quantity for G+7 building

Item No	DESCRIPTION	Unit	Cost with C-25 Concrete			Cost with C-40 Concrete		
			Qty	Rate	Amount	Qty	Rate	Amount
	1.A. SUBSTRUCTURE WORK **1.A.1 EXCAVATION & EARTH WORKS**							
1.A.1.1	Pit excavation for isolated footing to the depth below 1500mm from reduced level. Price shall be include 250mm working space in all sides.	m^3	608.57	115.89	70,523.56	570.35	115.89	66,095.30
1.A.1.2	Ditto item 1.A.1.1. but depth below 1500-3000mm from reduced level. Price shall be include 250mm working space in all sides.	m^3	981.57	135.14	132,650.32	877.83	135.14	118,630.24
1.A.1.3	Back fill around footings with non-expansive granular selected borrowed material and compact in layers of 200mm thick until compaction attaining 98% dry density.	m^3	94.30	368.06	34,706.45	80.13	368.06	29,492.85
1.A.1.4	Back fill around foundation coumn with non-expansive granular selected borrowed material and compact in layers of 200mm thick until compaction attaining 98% dry density.	m^3	1,190.20	368.06	438,068.20	1,122.52	368.06	413,159.14
1.A.1.5	Loaded and cart away surplus excavated material to a distance not exceeding 5km from the site.	m^3	1,590.14	141.00	224,212.84	1,448.18	141.00	204,196.61
	Total Carried to Summary………………………………………………….				**900,161.37**			**831,574.13**
	1.A.2 CONCRETE WORK							
1.A.2.1	50mm thick lean concrete in concrete class C-5, 150kgs of cement /m^3 of concrete							
	a. Under footings	m^2	303.01	93.13	28,219.66	281.04	93.13	26,173.10
	b.Under grade beam	m^2	83.69	93.13	7,794.47	70.36	93.13	6,553.15
1.A.2.2	Reinforced Concrete of class C-25 (concrete without concrete grade enhancer admixture) and C-40 (concrete with concrete grade enhancer admixture of 1.5% by weight of cement) with a minimum cement content of 450kg /m^3 and filled into form work and vibrated around steel reinforcement. (Form work and Rebar measured separately.)							
	a. Footing	m^3	263.56	2,731.99	720,050.37	218.37	3,280.18	716,288.16
	b.Foundation column	m^3	26.93	3,258.10	87,738.68	18.18	3,806.29	69,200.67
	c. Grade beam	m^3	37.66	2,890.48	108,861.43	28.00	3,438.67	96,298.43
1.A.2.3	Provide, cut and fix in position sawn structural wood or steel formwork which ever is appropriate.							
	a. Footing	m^2	330.64	228.24	75,464.17	277.98	228.24	63,445.23
	b.Foundation column	m^2	152.74	275.20	42,032.77	119.19	275.20	32,800.85
	c. Grade beam	m^2	257.47	228.24	58,764.33	230.36	228.24	52,576.55
1.A.2.4	Steel reinforcement according to structural drawings. Price includins bar cutting, bending, tying wires & placing in position.							
	a. Footing							
	Diamerer 6mm plain bar	kg	-	96.97	-	-	96.97	-
	Diamerer 8mm deformed bar	kg	-	78.11	-	-	78.11	-
	Diamerer 10mm deformed bar	kg	-	77.54	-	-	77.54	-
	Diamerer 12mm deformed bar	kg	-	72.43	-	-	72.43	-
	Diamerer 14mm deformed bar	kg	-	73.15	-	-	73.15	-
	Diamerer 16mm deformed bar	kg	-	72.16	-	-	72.16	-
	Diamerer 20mm deformed bar	kg	15,336.75	72.65	1,114,185.89	13,920.39	72.65	1,011,289.99
	Diamerer 24mm deformed bar	kg	-	68.23	-	-	68.23	-
	Diamerer 32mm deformed bar	kg	-	62.66	-	-	62.66	-
	b. Foundation column							
	Diamerer 6mm plain bar	kg	-	96.97	-	102.34	96.97	9,923.98
	Diamerer 8mm deformed bar	kg	223.03	78.11	17,420.15	-	78.11	-
	Diamerer 10mm deformed bar	kg	-	77.54	-	-	77.54	-
	Diamerer 12mm deformed bar	kg	-	72.43	-	-	72.43	-
	Diamerer 14mm deformed bar	kg	-	73.15	-	-	73.15	-
	Diamerer 16mm deformed bar	kg	-	72.16	-	-	72.16	-
	Diamerer 20mm deformed bar	kg	-	72.65	-	-	72.65	-
	Diamerer 24mm deformed bar	kg	10,533.10	68.23	718,620.80	6,996.80	68.23	477,356.72
	Diamerer 32mm deformed bar	kg	-	62.66	-	-	62.66	-
	Total Carried to Summary……………………………………….				**2,979,152.73**			**2,561,906.82**

Item No	DESCRIPTION	Unit	Cost with C-25 Concrete			Cost with C-40 Concrete		
			Qty	Rate	Amount	Qty	Rate	Amount
	1.B SUPER-STRUCTURE **1.B.1 CONCRETE WORK**							
1.B.1.1	Reinforced Concrete of class C-25 (concrete without concrete grade enhancer admixture) and C-40 (concrete with concrete grade enhancer admixture of 1.5% by weight of cement) with a minimum cement content of 450kg /m^3 and filled into form work and vibrated around steel reinforcement. (Form work and Rebar measured separately.)							
	a. Sample Elevation Column	m^3	53.69	3,258.10	174,933.21	36.26	3,806.29	138,001.16
	b. Sample Staircase	m^3	4.78	2,695.26	12,876.62	4.19	3,243.46	13,576.79
	c. Sample Floor Beam	m^3	25.24	2,890.48	72,961.44	18.70	3,438.67	64,303.18
	d. Sample Floor Slab	m^3	155.18	2,695.26	418,253.97	136.92	3,243.46	444,108.94
1.B.1.2	Provide, cut and fix in position sawn structural wood or steel formwork which ever is appropriate.							
	a. Sample Elevation Column	m^2	303.49	275.20	83,519.22	238.22	275.20	65,555.75
	b. Sample Staircase	m^2	28.12	228.24	6,418.02	27.57	228.24	6,292.76
	c. Sample Floor Beam	m^2	246.89	228.24	56,348.39	220.65	228.24	50,360.42
	d. Sample Floor Slab	m^2	932.68	228.24	212,871.20	930.34	228.24	212,338.27
1.B.1.3	Steel reinforcement according to structural drawings. Price includins bar cutting, bending, tying wires & placing in position.							
	a. Sample Elevation Column							
	Diamerer 6mm plain bar	kg	-	96.97	-	247.43	96.97	23,993.20
	Diamerer 8mm deformed bar	kg	512.96	78.11	40,066.35	-	78.11	-
	Diamerer 10mm deformed bar	kg	-	77.54	-	-	77.54	-
	Diamerer 12mm deformed bar	kg	-	72.43	-	-	72.43	-
	Diamerer 14mm deformed bar	kg	-	73.15	-	-	73.15	-
	Diamerer 16mm deformed bar	kg	-	72.16	-	84.87	72.16	6,124.37
	Diamerer 20mm deformed bar	kg	3,019.20	72.65	219,339.22	1,716.80	72.65	124,722.30
	Diamerer 24mm deformed bar	kg	7,801.90	68.23	532,284.42	4,846.63	68.23	330,661.53
	Diamerer 32mm deformed bar	kg	-	62.66	-	-	62.66	-
	b. Sample Floor Beam							
	Diamerer 6mm plain bar	kg	-	96.97	-	120.41	96.97	11,676.28
	Diamerer 8mm deformed bar	kg	245.88	78.11	19,205.02	-	78.11	-
	Diamerer 10mm deformed bar	kg	-	77.54	-	-	77.54	-
	Diamerer 12mm deformed bar	kg	-	72.43	-	-	72.43	-
	Diamerer 14mm deformed bar	kg	-	73.15	-	-	73.15	-
	Diamerer 16mm deformed bar	kg	518.28	72.16	37,400.11	449.21	72.16	32,416.09
	Diamerer 20mm deformed bar	kg	-	72.65	-	-	72.65	-
	Diamerer 24mm deformed bar	kg	1,104.78	68.23	75,373.52	988.81	68.23	67,461.27
	Diamerer 32mm deformed bar	kg	-	62.66	-	-	62.66	-
	c. Sample Floor Slab							
	Diamerer 6mm plain bar	kg	159.51	96.97	15,467.19	159.51	96.97	15,467.19
	Diamerer 8mm deformed bar	kg	3,121.67	78.11	243,827.73	2,819.96	78.11	220,261.82
	Diamerer 10mm deformed bar	kg	3,619.22	77.54	280,647.87	4,468.80	77.54	346,527.62
	Diamerer 12mm deformed bar	kg	-	72.43	-	-	72.43	-
	Diamerer 14mm deformed bar	kg	-	73.15	-	-	73.15	-
	Diamerer 16mm deformed bar	kg	-	72.16	-	-	72.16	-
	Diamerer 20mm deformed bar	kg	-	72.65	-	-	72.65	-
	Diamerer 24mm deformed bar	kg	-	68.23	-	-	68.23	-
	Diamerer 32mm deformed bar	kg	-	62.66	-	-	62.66	-
	d. Sample floor staircase							
	Diamerer 6mm plain bar	kg	-	96.97	-	-	96.97	-
	Diamerer 8mm deformed bar	kg	117.50	78.11	9,177.72	99.85	78.11	7,799.15
	Diamerer 10mm deformed bar	kg	91.91	77.54	7,126.89	91.32	77.54	7,080.99
	Diamerer 12mm deformed bar	kg	-	72.43	-	-	72.43	-
	Diamerer 14mm deformed bar	kg	169.26	73.15	12,380.96	169.26	73.15	12,380.96
	Diamerer 16mm deformed bar	kg	-	72.16	-	-	72.16	-
	Diamerer 20mm deformed bar	kg	-	72.65	-	-	72.65	-
	Diamerer 24mm deformed bar	kg	-	68.23	-	-	68.23	-
	Diamerer 32mm deformed bar	kg	-	62.66	-	-	62.66	-
	Total Carried to Summary……………………………				**2,530,479.08**			**2,201,110.05**
	1.B.2 FINISHING WORK							
1.B.2.1	Apply two coats of plastering in cement mortar (1:3) .Price shall include chiseling,pre-cleaning and preparation of the surface.							
	a. Sample Elevation Column	m^2	298.45	161.26	48,126.78	234.86	161.26	37,871.68
	b. Sample Floor Beam	m^2	224.39	161.26	36,184.37	200.68	161.26	32,359.88
	Total Carried to Summary…………………………………				**84,311.15**			**70,231.56**
	1.B.3 PAINTING							-
1.B.3.1	Apply three coats of plastic emulsion paint. Price shall include pre - cleaning & preparation of the surface.							-
	a. Sample Elevation Column	m^2	298.45	53.31	15,911.17	234.86	53.31	12,520.74
	b. Sample Floor Beam	m^2	224.39	53.31	11,962.90	200.68	53.31	10,698.49
	Total Carried to Summary…………………………				**27,874.07**			**23,219.23**

Table G.3 Priced bill of quantity for G+12 building

Item No	DESCRIPTION	Unit	Cost with C-25 Concrete			Cost with C-40 Concrete		
			Qty	Rate	Amount	Qty	Rate	Amount
	1.A. SUBSTRUCTURE WORK **1.A.1 EXCAVATION & EARTH WORKS**							
1.A.1.1	Pit excavation for isolated footing to the depth below 1500mm from reduced level. Price shall be include 250mm working space in all sides.	m^3	1,063.87	115.89	123,286.29	931.93	115.89	107,996.85
1.A.1.2	Ditto item 1.A.1.1. but depth below 1500-3000mm from reduced level. Price shall be include 250mm working space in all sides.	m^3	1,942.56	135.14	262,518.64	1,593.83	135.14	215,391.59
1.A.1.3	Back fill around footings with non-expansive granular selected borrowed material and compact in layers of 200mm thick until compaction attaining 98% dry density.	m^3	170.86	368.06	62,887.16	137.06	368.06	50,444.81
1.A.1.4	Back fill around foundation coumn with non-expansive granular selected borrowed material and compact in layers of 200mm thick until compaction attaining 98% dry density.	m^3	2,080.55	368.06	765,773.38	1,827.68	368.06	672,701.87
1.A.1.5	Loaded and cart away surplus excavated material to a distance not exceeding 5km from the site.	m^3	3,006.43	141.00	423,912.68	2,525.77	141.00	356,138.25
	Total Carried to Summary……………………………….				**1,638,378.15**			**1,402,673.37**
	1.A.2 CONCRETE WORK							
1.A.2.1	50mm thick lean concrete in concrete class C-5, 150kgs of cement /m^3 of concrete							
	a. Under footings	m^2	571.05	93.13	53,182.06	529.42	93.13	49,305.24
	b.Under grade beam	m^2	93.16	93.13	8,675.86	80.61	93.13	7,507.34
1.A.2.2	Reinforced Concrete of class C-25 (concrete without concrete grade enhancer admixture) and C-40 (concrete with concrete grade enhancer admixture of 1.5% by weight of cement) with a minimum cement content of 450kg /m^3 and filled into form work and vibrated around steel reinforcement. (Form work and Rebar measured separately.)							
	a. Footing	m^3	679.28	2,731.99	1,855,786.73	500.23	3,280.18	1,640,833.36
	b.Foundation column	m^3	47.18	3,258.10	153,724.91	36.18	3,806.29	137,706.65
	c. Grade beam	m^3	46.58	2,890.48	134,634.88	32.22	3,438.67	110,798.89
1.A.2.3	Provide, cut and fix in position sawn structural wood or steel formwork which ever is appropriate.							
	a. Footing	m^2	620.30	228.24	141,575.20	492.10	228.24	112,315.26
	b.Foundation column	m^2	202.01	275.20	55,592.65	175.48	275.20	48,292.48
	c. Grade beam	m^2	280.88	228.24	64,106.54	227.09	228.24	51,829.53
1.A.2.4	Steel reinforcement according to structural drawings. Price includins bar cutting, bending, tying wires & placing in position.							
	a. Footing							
	Diamerer 6mm plain bar	kg	-	96.97	-	-	96.97	-
	Diamerer 8mm deformed bar	kg	-	78.11	-	-	78.11	-
	Diamerer 10mm deformed bar	kg	-	77.54	-	-	77.54	-
	Diamerer 12mm deformed bar	kg	-	72.43	-	-	72.43	-
	Diamerer 14mm deformed bar	kg	-	73.15	-	-	73.15	-
	Diamerer 16mm deformed bar	kg	-	72.16	-	-	72.16	-
	Diamerer 20mm deformed bar	kg	-	72.65	-	-	72.65	-
	Diamerer 24mm deformed bar	kg	37,647.65	68.23	2,568,510.78	32,208.12	68.23	2,197,398.66
	Diamerer 32mm deformed bar	kg	-	62.66	-	-	62.66	-
	b. Foundation column							
	Diamerer 6mm plain bar	kg	-	96.97	-	-	96.97	-
	Diamerer 8mm deformed bar	kg	256.95	78.11	20,070.01	247.63	78.11	19,342.20
	Diamerer 10mm deformed bar	kg	-	77.54	-	-	77.54	-
	Diamerer 12mm deformed bar	kg	-	72.43	-	-	72.43	-
	Diamerer 14mm deformed bar	kg	-	73.15	-	-	73.15	-
	Diamerer 16mm deformed bar	kg	-	72.16	-	-	72.16	-
	Diamerer 20mm deformed bar	kg	-	72.65	-	-	72.65	-
	Diamerer 24mm deformed bar	kg	-	68.23	-	-	68.23	-
	Diamerer 32mm deformed bar	kg	31,395.51	62.66	1,967,242.80	19,362.98	62.66	1,213,284.21
	Total Carried to Summary…………………………………..				**7,023,102.45**			**5,588,613.82**

Item No	DESCRIPTION	Unit	Cost with C-25 Concrete			Cost with C-40 Concrete		
			Qty	Rate	Amount	Qty	Rate	Amount
	1.B SUPER-STRUCTURE **1.B.1 CONCRETE WORK**							
1.B.1.1	Reinforced Concrete of class C-25 (concrete without concrete grade enhancer admixture) and C-40 (concrete with concrete grade enhancer admixture of 1.5% by weight of cement) with a minimum cement content of 450kg /m^3 and filled into form work and vibrated around steel reinforcement. (Form work and Rebar measured separately.)							
	a. Sample Elevation Column	m^3	93.42	3,258.10	304,370.93	71.79	3,806.29	273,272.25
	b. Sample Staircase	m^3	5.05	2,695.26	13,604.34	4.19	3,243.46	13,576.79
	c. Sample Floor Beam	m^3	31.56	2,890.48	91,232.15	18.84	3,438.67	64,776.00
	d. Sample Floor Slab	m^3	182.57	2,695.26	492,063.49	136.92	3,243.46	444,108.94
1.B.1.2	Provide, cut and fix in position sawn structural wood or steel formwork which ever is appropriate.							
	a. Sample Elevation Column	m^2	397.72	275.20	109,451.58	352.32	275.20	96,956.32
	b. Sample Staircase	m^2	28.12	228.24	6,418.02	27.57	228.24	6,292.76
	c. Sample Floor Beam	m^2	264.24	228.24	60,309.26	235.87	228.24	53,834.18
	d. Sample Floor Slab	m^2	936.18	228.24	213,670.60	930.34	228.24	212,338.27
1.B.1.3	Steel reinforcement according to structural drawings. Price includins bar cutting, bending, tying wires & placing in position.							
	a. Sample Elevation Column							
	Diamerer 6mm plain bar	kg	-	96.97	-	-	96.97	-
	Diamerer 8mm deformed bar	kg	576.21	78.11	45,006.94	627.45	78.11	49,008.86
	Diamerer 10mm deformed bar	kg	-	77.54	-	-	77.54	-
	Diamerer 12mm deformed bar	kg	-	72.43	-	-	72.43	-
	Diamerer 14mm deformed bar	kg	-	73.15	-	-	73.15	-
	Diamerer 16mm deformed bar	kg	-	72.16	-	1,370.03	72.16	98,864.80
	Diamerer 20mm deformed bar	kg	434.13	72.65	31,538.97	2,348.27	72.65	170,597.17
	Diamerer 24mm deformed bar	kg	797.92	68.23	54,438.18	8,141.75	68.23	555,471.05
	Diamerer 32mm deformed bar	kg	28,289.71	62.66	1,772,633.02	-	62.66	-
	b. Sample Floor Beam							
	Diamerer 6mm plain bar	kg	-	96.97	-	145.74	96.97	14,132.52
	Diamerer 8mm deformed bar	kg	260.80	78.11	20,370.27	-	78.11	-
	Diamerer 10mm deformed bar	kg	-	77.54	-	-	77.54	-
	Diamerer 12mm deformed bar	kg	-	72.43	-	-	72.43	-
	Diamerer 14mm deformed bar	kg	-	73.15	-	-	73.15	-
	Diamerer 16mm deformed bar	kg	598.16	72.16	43,164.49	631.47	72.16	45,568.21
	Diamerer 20mm deformed bar	kg	-	72.65	-	-	72.65	-
	Diamerer 24mm deformed bar	kg	1,153.97	68.23	78,729.86	1,133.19	68.23	77,312.20
	Diamerer 32mm deformed bar	kg	-	62.66	-	-	62.66	-
	c. Sample Floor Slab							
	Diamerer 6mm plain bar	kg	159.51	96.97	15,467.19	159.51	96.97	15,467.19
	Diamerer 8mm deformed bar	kg	3,406.94	78.11	266,110.02	2,819.96	78.11	220,261.82
	Diamerer 10mm deformed bar	kg	3,171.93	77.54	245,963.33	4,468.80	77.54	346,527.62
	Diamerer 12mm deformed bar	kg	-	72.43	-	-	72.43	-
	Diamerer 14mm deformed bar	kg	-	73.15	-	-	73.15	-
	Diamerer 16mm deformed bar	kg	-	72.16	-	-	72.16	-
	Diamerer 20mm deformed bar	kg	-	72.65	-	-	72.65	-
	Diamerer 24mm deformed bar	kg	-	68.23	-	-	68.23	-
	Diamerer 32mm deformed bar	kg	-	62.66	-	-	62.66	-
	d. Sample floor staircase							
	Diamerer 6mm plain bar	kg	-	96.97	-	-	96.97	-
	Diamerer 8mm deformed bar	kg	117.50	78.11	9,177.72	99.85	78.11	7,799.15
	Diamerer 10mm deformed bar	kg	92.80	77.54	7,195.75	91.32	77.54	7,080.99
	Diamerer 12mm deformed bar	kg	-	72.43	-	-	72.43	-
	Diamerer 14mm deformed bar	kg	169.26	73.15	12,380.96	169.26	73.15	12,380.96
	Diamerer 16mm deformed bar	kg	-	72.16	-	-	72.16	-
	Diamerer 20mm deformed bar	kg	-	72.65	-	-	72.65	-
	Diamerer 24mm deformed bar	kg	-	68.23	-	-	68.23	-
	Diamerer 32mm deformed bar	kg	-	62.66	-	-	62.66	-
	Total Carried to Summary……………………				**3,893,297.08**			**2,785,628.07**
	1.B.2 FINISHING WORK							
1.B.2.1	Apply two coats of plastering in cement mortar (1:3) .Price shall include chiseling,pre-cleaning and preparation of the surface.							
	a. Sample Elevation Column	m^2	391.42	161.26	63,119.10	347.82	161.26	56,087.55
	b. Sample Floor Beam	m^2	240.03	161.26	38,706.08	200.35	161.26	32,307.47
	Total Carried to Summary……………………				**101,825.18**			**88,395.03**
	1.B.3 PAINTING							-
1.B.3.1	Apply three coats of plastic emulsion paint. Price shall include pre - cleaning & preparation of the surface.							-
	a. Sample Elevation Column	m^2	391.42	53.31	20,867.78	347.82	53.31	18,543.08
	b. Sample Floor Beam	m^2	240.03	53.31	12,796.60	200.35	53.31	10,681.16
	Total Carried to Summary……………………				**33,664.38**			**29,224.24**